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NASA CR. 147397

C-4546

SPACE SHUTTLE
ON-ORBIT FLIGHT CONTROL
SOFTWARE REQUIREMENTS
(Preliminary Version)

December 1975

Recommended for Inclusion in
Space Shuttle Orbiter
Orbital Flight Test
Level C
Functional Subsystem
Software Requirements Document
Guidance, Navigation and Control
Part C

Flight Control

(NASA-CR-147397) SPACE SHUTTLE ON-ORBIT FLIGHT CONTROL SOFTWAFE REQUIREMENTS, PRELIMINARY VERSION (Draper (Charles Stark) Lab., Inc.) 219 p HC \$7.75 CSCL 22B

N76-15241

Unclas 08470

G3/18



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HINSON SPACE CENTER
OUSTON, TEXAS

The Charles Stark Draper Laboratory, Inc.

Cambridge, Massachusetts 02139

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#### ACKNOWLEDGMENT

This report was prepared by The Charles Stark Draper Laboratory, Inc. under Contract NAS 9-13809 with the National Aeronautics and Space Administration.

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Tables specifying OFC control law function module interface requirements, constants and initialization requirements are contained in the subsections describing those modules. Refer to the Table of Contents.

#### 3. Overview

#### 3.1 Relationship to Other GN&C Functions

The GN&C on-orbit flight control function is accomplished in a software module referred to as the Flight Control (FC) or On-Orbit Flight Control (OFC) module. Figure 3.1-1 shows the relationship of the FC module to other GN&C major functions.

#### 3.2 On-Orbit Flight Control Module Overview

Figure 3.2-1 illustrates the interface categories of the FC module, and indicates the general functional relationship of the reconfiguration logic and control law implementation within the FC module.

#### 3.3 Abbreviations

The following specialized acronyms or abbreviations are used in this publication:

cg	center of gravity
DAP	digital autopilot
D&C	Display and Control
FC	Flight Control
GN&C	Guidance, Navigation and Control
GUID	Guidance
MSC	Moding, Sequencing, and Control
NAV	Navigation
OFC	On-Orbit Flight Control
OMS	Orbital Maneuvering System
RCS	Reaction Control System
RHC	Rotational Hand Controller
RM	Redundancy Management
SF	specialist function
SOP	Subsystem Operating Procedure
TBD	to be determined
THC	Translational Hand Controller
TVC	thrust vector control

The tabular parameter descriptions in Section 4 use the following type code:

A(i) - Array (i) V(i) - Vector (i) M(i,j) - Matrix (i,j)

Figure 3.1-1. Relationship of FC module to other GN&C major functions.

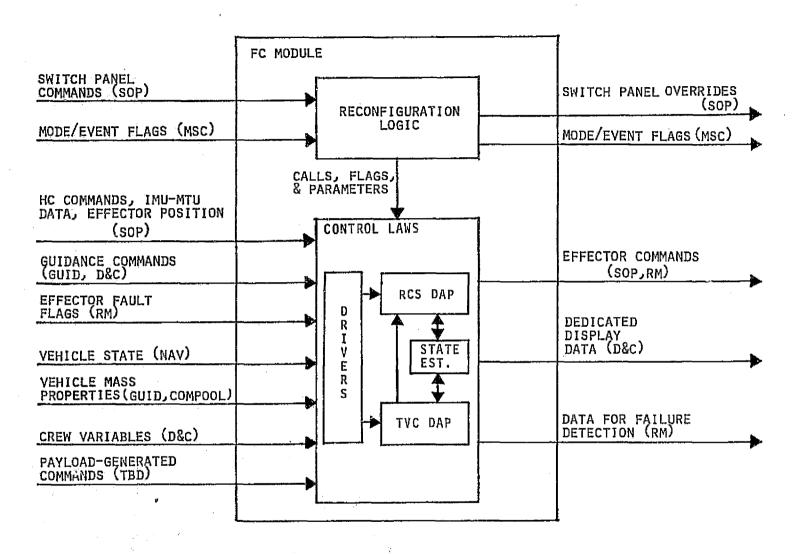


Figure 3.2-1. Relationship of FC module reconfiguration logic and control laws.

S - Scalar

B - Boolean

I - Integer

Example: A(3)I signifies an array of three integers.

### 4. Functional Requirements

#### 4.1 Interface Requirements

Overall interface requirements for the OFC module are given in Tables 4.1-1 and 4.1-2. This interface specification presupposes the existence of two specialized software modules (possibly located within the SOP group) to interface the OFC module with the rotational hand controller and the switch panel. RHC\_READ will convert the controller scalar outputs to integer form (with a range of -1,0,1, where a nonzero value indicates the controller is out of detent and gives the sense of the deflection) and will set a flag when the controller is deflected beyond the soft stop. The routine will incorporate hysteresis to prevent chatter at the switching points. PANEL\_SWITCH\_INTERP will convert the panel switch settings to a form directly useable by the OFC module. In particular, the module will provide the following:

Discretes		Integers	Scalars
High/low rotation acceleration	Manual	rotation submode	Attitude deadband
High/low translation acceleration	Manual	translation submode	Manual rotation dis- crete rate
Nominal/vernier RCS jets			Manual rotation pulse size
			Manual translation pulse size
			Off-axis rate thresholds for compensation

Some of the scalars may be selected from a pad-loaded pool using DAP load A/B switches, and others may be selected by dedicated switches such as pure/cross-coupled, high/low deadband, etc. PANEL\_SWITCH\_INTERP will also accept override inputs from the OFC module when certain RCS parameters must be forced, as during RCS assistance of TVC, and will be responsible for illuminating the switch annunciators to acknowledge a selection or call attention to an override condition.

TABLE 4.1-1 INPUT PARAMETERS FOR THE OFC MODULE

i hyhe i hyhe i	DESCRIPTION	SOURCE	TYPE	I I I RANGE	t t t turit L	   SAMPLF  PATE (HZ)	  UPTATT FATE   FEQ'D (HZ)
Panel Switch -  Derived Commands		   	   	 ! !	1 !	     	<u> </u>
DEADBAND	Attitude deadband	PANEL_SWITCH_INTERP	A (3) S	TBD	deg	1 25	TBD
i –	Derived body angular rate during deflection of rotational hand controller in manual discrete rotation submode	PANEL_SWITCH_INTERP	A (3) S	TBD	deg/s     	25     1 	TBF I
HOK_VERNIER_SW	RCS nominal/vernier jet select   (1=nominal; 0=vernier)	PANEL_SWITCH_INTERP	В 	10,1	none 	<b>2</b> 5	THD
OFF_AXIS_COMP_THRE-	Threshold for off-axis compensation firings	PANEL_SWITCH_INTERP	λ (6) S	TBD	f/s,deg/s	25 	TB:
ROT_H3_LO_SW	Rotational acceleration level select (1=high; 0=low)	PANEL_SWITCH_INTERP	A (3) B	10,1	none	25 	TBD I
	Hanual rotation submode select   (1=accel; 2=pulse; 3=discrete)	PANEL_SWITCH_INTERP	λ(3) I	11,2,3	inone	25   	TBE
	Desired body angular rate change per deflection of rotational hand controller in manual pulse rotation submode	PANEL_SWITCH_INTERP	A (5) S	TBD	deg/s   	25   	TBP
	Translational acceleration level select (1=high; 0=low)	PANEL_SWITCH_INTERP	A (3) B	[0,1	none	25	TEC
TEANS_OPTION	Manual translation submode	PANEL_SWITCH_INTERP	A (3) I	11,2	none 	1   25 	TBF
j – – 4	Desired velocity change per deflection of translational hand controller in manual pulse translation submode	FANEL_SWITCH_INTERP	à (3) S	ITBD	f/s       	25 	TBD
Bode/Event Flags		 	   	 I L	   L	   	1 1

TABLE 4.1-1 INPUT PARAMETERS FOR THE OFC MODULE

NAME   WAME	DESCRIPTION	I I Source	I I TYPE	I I I RANGE	UNIT	i   Sample  Rate (HZ)	  UPDATE BATE  REO'D (HZ)
RCS_ROTATION	RCS rotation mode enable   (1=enable)	i i asc	B	10,1	none	125	TBD
RCS_1UTO_NAWUAL	[RCS auto/manual select (1=auto;   0=aanual)	HSC	IB	10,1	none	25	TBD
RYNK_TT&	Auto RCS rotation mode select (1=manenver: 0=hold)	KSC	į B	10,1	none	i 25 I	TED
TWO_AXIS	(Two axis maneuver enable ((1=enable)	i HSC	В	10,1	none	5/6	TBD
THREE_AXIS	(Three axis maneuver enable (1=enable)	i MSC	B	10,1	none	5/6 	TBD
OMS_PRETHRUST [	OMS prethrust maneuver enable (1=enable)	KSC	( B	10,1	Inone	5/6 	TBD I
LCL_VERT_ATT	Local vertical maneuver enable   (1=enable)	MSC	IB I	[0,1	none	5/6 	TBD
PAYLD_SUP_CBUS	Payload supplied commands   Faneuver enable (1=enable)	MSC	B	10,1 !	none	15/6	TED I
TRACKING	(Tracking maneuver enable (1=énable)	l MSC	] B	10,1	none	15/6	TBC   
IBBQ	Barbecue maneuver enable   (1=enable)	MSC	[B	10,1	Inone	5/6 	THD
ECS_TRANSLATION	RCS translation mode enable (1=enable)	H5C 	I B	<u>[0,1</u> ].	none	125	TBD I
OHS_ARH_REG	OMS engines arming request   (1=request)	HSC 	] A (2) B	10,1	Inone	125	[TBD
ONS_ON_REQ	OMS engines turn-on request (1=request)	i HSC	(A (2) B	10,1	none	125	125
TYC_AUTO_HANUAL	TYC auto/manual select (1=auto;   0=manual)	i ksc I	1 B	[0,1 i	[none	25   1	TEC I

Ę,

TABLE 4.1-1 IMPUT PARAMETERS FOR THE OFC HODULE

NAHE	DESCRIPTION	i i source	   TYPE	   RANGE 	 		  UPPATE PATE  IIO'D (HZ) 
OFC_RESTART	OFC module initialization flag   (1=init)	MSC	∏B !	10,1	j none I	125	T BD
RIM	OMS gishal trim value select [{1=closed lcop: use value  remaining from previous OMS  burn: 0=open loop: use value  computed from expected cg  location	iksc i	B	C , 1             	none    -       	1/man euv er 	no  requirement 
HC Commands		   	!	<u> </u>	 ] <sub>1</sub>		
RHC	Rotational hand controller  deflection	SOF	(A (3) S	TBD	deg	[25	TED
	Translational hand controller command	SOP	[A (3) I	[-1, 0, 1	none	125 	TBD
	Rotational hand controller	RHC_READ	[ A (3) I	1-1,0,1	none	25 	TBD
SOFT_STOP	Flag indicating rotational hand  controller is deflected beyond  soft atop	RHC_READ	A (3) B	10,1	none   	25   	TBD
Guidance Commands			!	1	<u> </u>	]	
	Commanded terminal LMU gimbal  angles	GUID or D&C	A (3) S	- 18C < x  <= 18C	deg 	1/maneover	no requirement
	Commanded vehicle angular rate is stable member axes	GUID	V (3) S	T BD	deg/s 	25 	25
	Unit vector specifying commanded  pointing direction, including  initial ONS thrust direction in  stable member axes	GUID OF DEC	Y (3) S         	1-1 to +1	none    - 		no requirement

TABLE 4.1-1 INPUT PARAMETERS FOR THE OFC MODULE

NAME	DESCRIPTION	Source	TYPE	   RANGE	i I UNIT	SAMPLE RATE (HZ)	(UPDATE FATE  REQ'D (NZ)
BAGO	PESCHIATION		LTIPE	I HANGE	I ONTI	L L L (NO)	1 (us)
BODY_POINTING_VECT- OR	Unit vector, in body axes, to be aligned with POINTING_VECTOR_CND	GUID OF DEC	V (3) S	-1 to +1	none 	5/6 	no  requirement
	or with respect to local vertical		i [				
DELTA_Y_CHD	Commanded translational velocity  change 	GUID OF DEC	V (3) S	TBD   	f/s   	25     1	no  requirement
Payload-Generated	1			1		1	
and Tracking Commands				] • [		İ	
Tad	<u> </u>			! !	   	1	<u> </u>
INU KTU Data			•				
<u>, 1944 - Landina de la compansión de la compansión de la compansión de la compansión de la compansión de la c</u>	<u>i</u>	<u> </u>		1		1	
GIMBAL_ANGLES	IMU gimbal angles	SOP 	(A (3) S	-180 < x  <= 180	l deg	25 	25 
DELTA_V	[IMU accelerometer data; vehicle  velocity change since previous  sampling	I SOP	V (3) S	TBD	f/s   	1 25 1 1	TBD
THOW	INU data time tag	sop	Ţs	I IID	<u>                                     </u>	5/6	  25
Yehicle State		<u> </u>				Ţ	
POSITION	Vehicle position in stable   member axes, referred to   geocenter	NAY	V (3) S	T BD	£	5/6   	TTBD
VELOCITY	Yehicle velocity in stable  member axes, referred to  geocenter	I NAV	]V (3) S	TBD	f/s	15/6	TED
Vehicle Mass				 [	   	<u> </u>	1
Properties	I L	l L	L	. <u>l</u> _	 	1 	   <b> </b>

CU

TABLE 4.1-1 INPUT PARAMETERS FOR THE OFC MODULE

NAME	DESCRIPTION	l l j source T	I I I TYFE	I     BANGE 	UNIT		  UPDATE RATE  FFO'D (HZ)
[VEHICLE_CG	Vehicle center of gravity	5 P	17 (3) S	TBD	f	1/maneuver	no  requirement
VERICLE_INVERSE_IN-	- Inverse of vehicle inertia	SF	M (3,3) S	TBD	1/ ((slug) -   (f) (f)) 		no  requirement
Effector Fault		I !		] 		   	
JPAIL	RCS   failure (1=fail)	RH	X (44) B	10, 1	none	25	25
OHS_FAIL_DETECT	OMS failure detected (1=detected)	IRM	IB !	10, 1	none	   25 	25
JFAIL_CHANGE	Flag indicating change in JFAIL   (1=changed)	ind .	IB	10, 1	none	   25 	25
ONS_FAIL_DETECT	ONS failure detected   (1=detected)	RM 	[B	10, 1	none	25	25
OMS1_FAIL	OMS1 failure identified   {1=identified}	IRM	IB	[0, 1	поле	1 25	1
OMS2_FAIL 	JOMS2 failure identified (1=identified)	I RH	B 	(0, 1  -	none	25   	25
Effector Position		<u> </u>	]	]		<u> </u>	
OBS1_PITCH_YAW	10HS1 engine pitch and yaw	SOP	1A (2) 5	TBD	[geg	25	25
OHS2_PITCH_YAW	OMS2 engine pitch and yaw	ISOP	1 A (2) S	OGT!	deg 	25 	25
Crew Variables		! !	<u></u>	[	1		   
HANDESIE_BODYRATE	Desired magnitude of body angular rate in automatic lattitude maneuvers	DEC   	S   	C to 5	deg/s		no requirement

TABLE 4.1-1 INPUT PARAMETERS FOR THE OFC HODULE

WANE	DESCRIPTION	l I SOURCE I	TABE	   RANGE	I I UNIT		UPDATE RATE REO'D (HZ)
BARBECUE_RATE	Desired barbecus-mode angular	D&C	IS 	TBD	deg/s	1/maneuver	no  requirement
LO_PITCH_TAIL_HOSE	[Tail or nose jet select for low- level pitch rotation {1=tail; [0=nose]	pec	IB I	i 0 , 1	none 		no requirement
LO_YAW_TAIL_MOSE	Tail or nose jet select for low- lewel yaw rotation (1=tail; 0=nose)	DEC	B	[0,1 [	none	25   	no  reguirement
OHS_SELECT	To burn/not to burn status of   OHS engines (1=to burn; 0=not to   burn)	D&C	(A (2) B	10,1	none	1/maneuver   	no requirement

TABLE 4.1-2 OUTPUT PARAMETERS FOR THE OFC MODULE

NAME	DESCRIPTION	DESTINATION	TYPE	] HANGE	 		  Sample Pati  FEO'C (HZ)
Effector Commands	1	Į	ļ	]	<u> </u>	!	!
JOHLST	IRCS jet on commands (1=on)	ISOP,EH	[A (44) B	10,1	none	125	125
OMS1_ON_CHD	ONS1 engine on command (1=on)	ISOF, RX	] B	10,1	none	25	125
OHS2_ON_CHD	IOMS2 engine on command (1=on)	(SOP, RM	] B	ic.1	none	125	125
OHS_PITCH_YAW_CHD	OMS1 engine pitch and yaw  COMMands	SOP,RM	A (2) S	T BD	deg	25	125
OMS2_PITCH_YAW_CMD	OMS2 engine pitch and yaw  commands 	SOF, RM	A (2) S   	TBD   	deg	1 25 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	25   1 
Dedicated Display Data			<u> </u>	] 		   	
AUTO_GA_DESTRED	Desired INU gimbal angles   computed by automatic driver	DEC	j A (3) S	-180 < x  <= 180	deg	15/6	TED
GA_DESIRED	Desired IMU gimbal angles	, Dec	A (3) S	-180 < x  <= 180	deg	1 25 !	TBD
	Desired terminal IMU gimbal	DEC	A (3) S	-180 < x  <= 180	deg	1/maneuver	TBD
HANEUVER_COMPLETE	Flag signifying completion of maneuver	IDEC	B   I	10,1	Inone	15/6	TBD
RATE_EST	Body angular rate estimate	DEC	[ V (3 ) S	TBD	deg/s	[ 25	TBD
RATE_ERROR	Body angular rate error	ID&C	[V (3) 5	TED	deg/s	125	TBD
Data for Failure Detection				!		 	[ [
DISTURB_ACCEL_EST   (roll component)	Body angular disturbance  acceleration estimate	I BR	1 V (3) S		deg/((s) (-  s))	-125 !	125 !

TABLE 4.1-2 OUTPUT PARAMETERS FOR THE OFC MODULE

				·			
NAME	DESCRIPTION	   DESTINATION     DESTINATION	TYPE	   PANGE	i i tunit	UPDATE RATE (HZ)	I  SAMPLE RATE  FEO'D (HZ)
Panel Switch Overrides		1		 	I   	1	1
NOM_VERNIER_SN	NCS nominal/vernier jet select   (1=nominal; 0=vernier)	PANEL_SWITCH_INTERP	L I	10,1	none	] 25 	TBD
ROT_HI_LO_SW	Rotational acceleration level  select (1=high; 0=low)	PANEL_SWITCH_INTERP	A (3) B	10,1	none	1 25	[TBD
TRANS_HI_LO_SH	Translational acceleration level  select (1=high; 0=low)	PANEL_SWITCH_INTERP	A (3) B	10,1	l none	125	TBD
ROT_OPTION	Manual rotation submode solect   (1=accel; 2=pulse; 3=discrete)	PANEL_SWITCH_INTERP	I (3) I	11,2,3	l none	1 25	TBD
	<u> </u>	!	L	4			
Mode/Event Flags		<u> </u>	l	1	1	1	1
OFC_RESTART	OFC module initialization flag   (1=init)	i usc I	В	10,1	none   	125 1 L	TBD 

Also assumed in this definition is the existence of a specialist function (SF), which will enable the alteration of values in memory. The SF would operate through the displays and controls (D&C) software but on a nondedicated basis, enabling access to any region of memory.

#### 4.2 Detailed Functional Requirements

This section describes the functional requirements of the OFC module in two subsections, reconfiguration module and control law module.

#### 4.2.1 Reconfiguration Module

#### 4.2.1.1. Function

Figure 4.2.1.1-1 illustrates the major reconfiguration functions of OFC RECON and their general relationship to the configurationcontrolling inputs of the OFC module. The decision is first made as to whether TVC or RCS operations are needed. The required TVC or RCS driver modules are set up and executed, and the required component modules of the TVC and/or RCS DAP are likewise set up and executed. Setting up includes initializing, and specifying configuration-dependent parameters such as rates and gains, in response to a commanded mode or configuration change. Equally important to effecting such a change are the cleanup activities, which include forcing DAP outputs to zero or to nominal values when the particular DAP has been deactivated, and making last calls to certain DAP modules for the same pu\_ose. Execution includes selecting and sequencing the control law modules as dictated by the moding inputs. Not shown in the diagram are the more routine executive duties of OFC RECON, such as clocking the "slow" (5/6 Hz) driver modules, and calling the State Estimator modules every OFC minor cycle.

For clarity in presentation, the remainder of this section, which describes the OFC\_RECON execution-sequencing function, distinguishes among three types of variables. First, there are the controlling inputs, generated both externally to OFC and within the control laws, in meaningful logical combinations. Second, there are the resulting "outputs" of OFC\_RECON, consisting of sequenced calls to selected control law function modules. Third, there are the OFC modes, which are the definitions by which the OFC\_RECON functions and their purposes are made more easily understood.

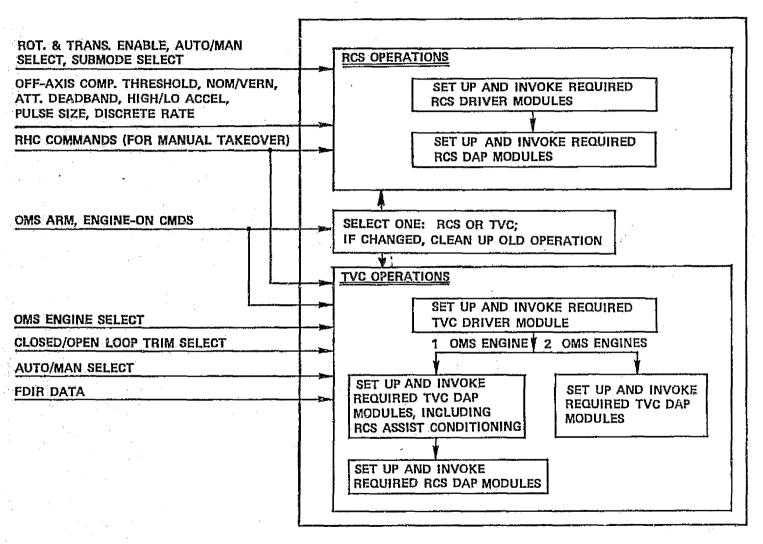


Figure 4.2.1.1-1. OFC reconfiguration module major functions.

Table 4.2.1.1-1 relates the first two variable types, in conjunction with the control law module block diagram, Figure 4.2.2-1. The "switches" in this diagram control data flow among the function modules, and their positions define which modules are needed and, to an extent, their sequencing requirements. (If, with a given switch configuration, module A's outputs are not received anywhere, then module A is not needed. Also, if module B drives only module A, it too is not needed. Generally, if B drives A and both are needed, B should precede A; however, exceptions to this can be found as "one cycle delays" in Figure 4.2.2-1.) Logical combinations of controlling inputs required for each switch position are given in the referenced table.

The first and third variable types are related in Table 4.2.1.1-2, which defines an OFC mode-submode-condition combination for each significant combination of inputs.

With the OFC modes defined, the OFC\_RECON actions for these modes are described in two ways. First, Table 4.2.1.1-3 relates the OFC modes to the requisite function modules by specifying a set of switch positions (referring again to Figure 4.2.2-1) for each modal subdivision. Second, the diagrams of Figure 4.2.1.1-2 present an OFC mode-by-mode specification of the required sequences in which the control law function modules must be invoked. The requirements are read vertically from the top of the diagram. Requirements for sequential execution are indicated with solid line arrows running down from "earlier" modules to "later" modules. For those cases in which two or more modules are at a given level there is no execution sequencing requirement among these modules.

For example, in diagram/mode I.A.1., module 1.4 (AUTO\_TVC) must be executed before module 4.4 in a given OFC minor cycle; similarly, module 4.6 must be executed prior to module 4.4. There is no requirement as to the execution sequence of 1.4 with respect to 4.6 (or 3.1). (Later developments may indicate that transport delays might be alleviated by executing one or the other of these first, but this document does not deal with such considerations at present.) Both modules 4.11 and 4.10 must be executed before 4.12 on a given FC cycle.

Table 4.2.1.1-1. Relationship between OFC RECON outputs and moding inputs (page 1 of 2).

(Refer t		MODING INPUT COMBINATION (See Note 1)
Fig. 4.2	POSITION	
Sl	A	RCS TRANSLATION NOM VERNIER SW-[RCS AUTO MANUAL +
(Note 2)	•	DETENT] - TRANS OPTION = 1 (ACCEL)
	В	RCS TRANSLATION · NOM VERNIER SW · [RCS AUTO MANUAL +
		DETENT] • TRANS OPTION = 2 (PULSE)
	C	RCS TRANSLATION NOM VERNIER SW-RCS AUTO MANUAL DETENT
	מ	RCS_TRANSLATION + NOM_VERNIER_SW
52	A	RCS_ROTATION.TWO_AXIS
	В	RCS_ROTATION.THREE_AXIS
	С	RCS_ROTATION • OMS_PRETHRUST
	D	RCS_ROTATION·BBQ
	E	[TWO_AXIS + THREE_AXIS + OMS_PRETHRUST + BBQ]
		+ RCS_ROTATION
S3	A	TWO_AXIS • RCS_ROTATION
į į	В	THREE_AXIS • RCS_ROTATION
	c ·	OMS_PRETHRUST-RCS_ROTATION
	ם	BBQ · RCS_ROTATION
	E	LCL_VERT_ATT • RCS_ROTATION
1	F	PAYLD_SUP_CMDS.RCS_ROTATION
}	G	TRACKING • RCS_ROTATION
ļ	н	RCS_ROTATION + [TWO_AXIS + THREE_AXIS + OMS_PRETHRUST
		+ BBQ + LCL_VERT_ATT + PAYLD_SUP_CMDS + TRACKING]
S4	A	RCS_ROTATION • RCS_AUTO_MANUAL • DETENT • ATT_MNVR
(Note 2)	В	RCS_ROTATION • RCS_AUTO_MANUAL • DETENT • ATT_MNVR
	С	RCS_ROTATION · [RCS_AUTO_MANUAL + DETENT] · ROT_OPTION
ļ		=3 (DISC) · SOFT_STOP
	מ	RCS_ROTATION + [RCS_AUTO_MANUAL + DETENT] • [ROT_
	<u> </u>	OPTION #3 (DISC) + SOFT_STOP]
S5	A	RCS_ASSIST_P_Y
1	В	RCS_ASSIST_P_Y
<b>S6</b>	A	RCS_ASSIST_ROLL
	В	RCS_ASSIST_ROLL
	!	

Table 4.2.1.1-1. Relationship between OFC RECON outputs and moding inputs (page 2 of 2).

(Refer Fig. 4.		MODING INPUT COMBINATION (See Note 1)
57	A	RCS_ASSIST_ROLL + [RCS_ROTATION·RCS_AUTO_MANUAL
(Note 2)		• DETENT] + [RCS_ROTATION - [RCS_AUTO_MANUAL + DETENT]
	В	•SOFTSTOP•ROT_OPTION=3(DISC)] RCS ASSIST ROLL•RCS ROTATION•[RCS AUTO MANUAL
	_	+ DETENT] · [SOFT_STOP + ROT_OPTION=1 (ACCEL)]
	С	RCS_ASSIST_ROLL.RCS_ROTATION.[RCS_AUTO_MANUAL
	D	+ DETENT] ·SOFT_STOP · ROT_OPTION=2 (FULSE)  RCS ROTATION · RCS ASSIST ROLL
58	. D	RCS_ROTATION + [RCS_TRANSLATION · NOM VERNIER SW]
56	<b>A</b> .	+ RCS ASSIST ROLL
	В	RCS_ROTATION · [RCS_TRANSLATION + NOM_VERNIER_SW]
		-RCS_ASSIST_ROLL
S9	. A	RCS_ASSIST_ROLL
	В	RCS_ASSIST_ROLL
S10	A	RCS_ASSIST_P_Y
	В	RCS_ASSIST_P_Y
S11	A	TVC_AUTO_MANUAL
	B	TVC_AUTO_MANUAL·RCS_ASSIST_P_Y TVC_AUTO_MANUAL·RCS_ASSIST_P_Y
S12	A	[OMS FAIL DETECT.TVC] + [OMS PRETHRUST.CLOSED OPEN
	(Note 2)	LOOP TRIM-ONE ENGINE]
	В	[OMS_PRETHRUST OMS_FAIL_DETECT] + [OMS_PRETHRUST
		·CLOSED_OPEN_LOOP_TRIM]
	С	OMS_SELECT_: OMS_SELECT_: OMS_PRETHRUST - CLOSED_OPEN_ LOOP_TRIM
S13	A	OMS FAIL DETECT • TVC
(Note 2)	В	[OMS_FAIL_DETECT.TVC] + [OMS_PRETHRUST.FIRST PASS
		•RCS]
\$14 (Note 4)	A	LATCH_ASSIST_PITCH_YAW-FAIL_ID-TVC
11000 11	В	LATCH_ASSIST_PITCH_YAW + FAIL_ID + TVC
51,5	A	TVC + OMS_PRETHRUST
	В	TVC.OMS_PRETHRUST

#### Notes:

- 1. Logical symbols used:  $+ = \text{or}, \oplus = \text{exclusive or}, \cdot = \text{and}, \\ \overline{x} = \text{not } x.$ 
  - The following mode abbreviations are used:

    TVC = [OMS\_ARM\_REQ\_+OMS\_ON\_REQ\_+OMS1\_FAIL] +

    [OMS\_ARM\_REQ\_+OMS\_ON\_REQ\_+OMS2\_FAIL]

    FAIL\_ID = OMS1\_FAIL + OMS2\_FAIL

    ONE\_ENGINE = OMS\_SELECT\_+OMS\_SELECT\_2

    RCS\_ASSIST\_ROLL = TVC+[FAIL\_ID + ONE\_ENGINE]

    RCS\_ASSIST\_P\_Y = RCS\_ASSIST\_ROLL+ASSIST\_PITCH\_YAW (See Note 4)

    DETENT = value of RHC STATE is 0.
- 3. The associated modules are executed only once during the OMS\_PRETHRUST initialization pass or during the first pass after FAIL\_ID.
- 4. OFC\_RECON logic permits cycling between execution of RCS\_ASSIST\_PITCH\_YAW and TVC\_LAW\_PITCH\_YAW and back to RCS\_ASSIST\_PITCH\_YAW once (both modules may not be executed in the same pass); once this cycling has occurred, OFC\_RECON logic is "latched" to invoke RCS\_ASSIST\_PITCH\_YAW for the duration of the OMS burn.

This is mechanized in OFC\_RECON as follows: ASSIST\_PITCH\_YAW is set to 1 if less than TBD time has elapsed since FAIL\_ID, and afterwards is controlled by the module PITCH\_YAW\_ASSIST\_COMPUTATION; however, if ASSIST\_PITCH\_YAW makes the successive transitions 1+0, 0+1, LATCH\_ASSIST\_PITCH\_YAW is set to 1 and holds ASSIST\_PITCH\_YAW = 1 for the remainder of the TVC mode.

In general, the sequential execution requirements are determined by the data flow requirements between OFC modules. Occasionally, however, an OFC module must provide OFC\_PECON with information to decide which modules to invoke or to determine parameter settings for subsequently invoked OFC modules. Also, in the case where an automatic driver is required to generate display data, but an attitude hold or manual driver is actually to control the RCS DAP, then the "controlling" driver must be called after the display-generating driver to overwrite the relevant RCS DAP commands. Such exceptional relationships are indicated in the diagrams with dashed lines rather than solid lines.

The diagrams are preceded by an outline listing the OFC modes in the order of the diagrams. The module numbering corresponds to that of the subsections of Section 4.2.2.

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Table 4.2.1.1-2. Relationships between moding inputs and OFC modes.

MODING INPUT COMBINATION (SEE NOTE 1)	 		OFC MODE.	SUBMODE & C	ONDITION (SEE NOTE 2)		
[OMS_ARM_REQ <sub>1</sub> • OMS_ON_REQ <sub>1</sub> • OMS1_FAIL1+ [OMS_ARM_REQ <sub>2</sub> • OMS_ON_REQ <sub>2</sub> • OMS2_FAIL]	TVC						
TVC_AUTO_MANUAL/ TVC_AUTO_MANUAL		AUTO/ MANUAL					
OMS_ARM_REQ <sub>1</sub> • OMS_ON_REQ <sub>1</sub> • OMS_ARM_REQ <sub>2</sub> • OMS_ON_REQ <sub>2</sub> • OMS_FAIL_DETECT		(SEE NOTE 3)	NOMINAL	. 2-ENGINE BL	JRN, NO FAILURE		
OMS_FAIL_DETECT • OMST_FAIL • OMS2_FAIL			FAILURE	DETECTION V	VITHOUT IDENTIFICATION		
[OMS1_FAIL + OMS2_FAIL + [OMS_SELECT <sub>1</sub> ⊕ OMS_SELECT <sub>2</sub> ]] • RCS_ASSIST_P_Y (SEE NOTE 4)			RCS ASSI	ST ROLL ONL	У		
RCS_ASSIST_P_Y (SEE NOTE 4)			RCS ASSI	ST ROLL AND	PITCH_YAW	]	_
( <tbd +<="" rcs_assist_roll)="" since="" td="" time=""><td> </td><td></td><td></td><td></td><td>UNCONDITIONAL</td><td></td></tbd>					UNCONDITIONAL		
LATCH_ASSIST_PITCH_YAW (SEE NOTE 4)						UNGONDITIONAL	
(>TBD TIME SIMCE RCS_ASSIST_ROLL) .						CONDITIONAL	
LATCH_ASSIST_PITCH_YAW (SEE NOTE 4)				_	·	CONDITIONAL	}
(OMS_ARM_REQ <sub>1</sub> + OMS_ON_REQ <sub>1</sub> + OMS1_FAIL) •  [OMS_ARM_REQ <sub>2</sub> + OMS_ON_REQ <sub>2</sub> + OMS2_FAIL)	ACS			···		· · · · · · · · · · · · · · · · · · ·	
RCS_ROTATION		ROTATION	1				
RCS_AUTO_MANUAL • (RHC_STATE = 0)	<del> </del>		AUTO	Ī			
ATT_MNVR	<b> </b> -			ATTITUDE			
ATT MNVR			<del> </del>	HOLD ATTITUDE			
		J	<del> </del>	MANEUVER		1	
TWO_AXIS		<b> </b>			TWO AXIS		
THREE_AXIS BBO					BARBEQUE	-	•
			- <del> </del> -		LOCAL VERTICAL		1.5
LCL_VERT_ATT	<b> </b> -	<u></u>	<b></b>	<b>-</b> -	PAYLOAD	-	
PAYLD_SUP_CMDS			<b> </b>		TRACKING	1	
TRACKING			ــــــــــــــــــــــــــــــــــــــ		OMSPRETHPUST	to projektor i navigalje	Salahiya

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ATT_MNVR		1777 1		MANEUVER	The State of green as a second		
TWO_AXIS					TWO AXIS		
THREE_AXIS					THREE AXIS	Ţ.	
BBQ					BARBEQUE		
LCL_VERT_ATT					LOCAL VERTICAL		
PAYLD_SUP_CMDS					PAYLOAD		
TRACKING					TRACKING		
OMS_PRETHRUST					OMS PRETHRUST MANEUVER AND OMS ENGINE TRIM		
CLOSED_OPEN_LOOP_TRIM						CLOSED+LOOP TRIM	
CLOSED_OPEN_LOOP_TRIM						OPEN-LOOP TRIM	
(OMS_SELECT <sub>1</sub> ⊕ OMS_SELECT <sub>2</sub> )							2 ENG,
OMS_SELECT <sub>1</sub> ⊕ OMS_SELECT <sub>2</sub>		,					1 ENG,
RCS_AUTO_MANUAL + [RHC_STATE ≠ 0]			MANUAL		_)		
[ROT_OPTIONAXIS = 1] + SOFT_STOPAXIS				ACCELERATI	ои		
[ROT_OPTIONAXIS = 2] • SOFT_STOPAXIS				PULSE	SEE NOTE 5		
IROT_OPTIONAXIS = 31 • SOFT_STOPAXIS		_		DISCRETE			
RCS_TRANSLATION • NOM_VERNIER_SW		TRANSLA- TION			-)		
RCS_AUTO_MANUAL • [RHC_STATE = 0]			AUT0	}			
RCS_AUTO_MANUAL +[HHC_STATE = 0]			MANUAL		\).		
TRANS_OPTIONAX(S = 1				ACCELERATI	ON (SEE NOTE 5)		
TRANS_OPTIONAXIS = 2				PULSE			

NOTES: 1. LOGICAL SYMBOLS USED: + = OR,  $\bigoplus = EXCLUSIVE OR$ , \* = AND,  $\overline{X} = NOT X$ .

- 2. ALL MODES IN A GIVEN CONTIGUOUS VERTICAL STACK ARE MUTUALLY EXCLUSIVE EXCEPT RCS ROTATION/TRANSLATION.
- 3. ALTHOUGH MUTUALLY EXCLUSIVE, AUTO/MANUAL TVC ARE TREATED TOGETHER TO AVOID REPETITION.
- 4. THIS CONDITION IS EXPLAINED IN TABLE 4.2.1 1-1.
- 5, MANUAL RCS SUBMODES MAY HE MIXED AMONG THE 3 AXES.

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Table 4.2.1.1-3. Relationship between OFC modes and OFC\_RECON outputs.

	OFC MODE, SUBMODIE & CONDITION						OFC_RECON OUTPUT (REFER TO FIG. 4.2.2-1) SWITCHES AND POSITIONS (NUMBERS IN PARENTHESES REFER TO NOTES)															
								SI	\$2	52	54	56	\$6	<b>S7</b>	SE	59	SIO	SIT	S12	S13	514	S15
		2 ENGINE	S. NO FAILUR	Ĕ.				D	[1]	Н	D	A	$\overline{}$	D	8	В	B	В	ä	Α	В	A
		FAIL DET	ECT, NO ID					I.	Н	1	1.	, A	<b>A</b>	D	11	8	B	18_	4	ß	В	
	AUTO		T ROLL ONLY	r					Ш	$\Box$		:A	В	A	1.	A	В	<u> </u>	Α	В		1
i		RCS AS	HIST ROLL	1	CONDITIONAL							В	В	A		^	^	C		8	A	1
		ANO H	TCH-YAW	1	UNCONDITIONAL	<u> </u>			Ш		Ш	В	В	٨	Α			C	Α.	8	В	4
TVC		2 ENGINE	S, NO FAILUR	E					LL	Ш	<u> </u>	A	┡	D	8	В	·B	Α.	В	Α	В	1
	ļ. <b>i</b>	FAIL DET	ECT, NO ID							LL.	Ш	A	A	D.	В	В	В	Α	Α.	В	В.	4
	MANUAL	RCS ASSIS	T ROLL ONLY	,						$\coprod$		Α.	В		۸	1.	3	A	A	H.	A	Щ
		HCS AS	SIST ROLL	1	CONDITIONAL				$\sqcup \!\!\! \perp$			₽	В	Ш.	1_1_	<u> </u>	Α.	A	A	В	A	Щ
		AND 75	TCH-YAW		UNCONDITIONAL			D	(1)	Ħ	Đ		В		<u>L</u>	٨	A	A	A	В	B	Α
			ATT, HOLD					(3)	(4)	(4)	В	A	A			(1)	[1]	111	[1]	(1)	Ш	В
				TWO AXIS	<del></del>				^	Α	Α			Ш	Ш	11	$\sqcup \sqcup$	Ш	$\Box$	LL.	ᄔ	Li_
			<b>!</b>	THREE AXIS					В	8	1.1_		11	<u> </u>	${f L}{f L}$	$\perp \! \! \! \! \! \! \! \perp$	Ш	Ш	$\sqcup \sqcup$	Ц.	$\sqcup \sqcup$	Ш
	İ			BARBECKIE					٥	D	$\coprod$		$\Pi$	Ш	Ш	$\perp$	Щ	Ш	$\sqcup \sqcup$	Ц.	-	- -
			1	LOCAL VERTICA	\L				E	Ę	Ш			Ш		$\bot \bot$	Щ	Ш		ᄔ	Ш	Ш-
	1	AUTO	ATTITUDE	PAYLOAD					E	F	Щ	Ш		Ш	<u> </u>	ᄔ	Ц.	Ш.	Ш		ĮĮ	Ш
			MANEUVER	TRACKING					E	G	Ш		$\coprod$		$\bot \bot$	Ц.	Ш	╀.	111-	(11		3
	HOTATION					OPEN-LOOP TRIM	2 ENGINES		C	¢	Ш	Ц.	<u> </u>	Ш	$\perp \perp$	11	LL.	11_	c	В	Ш	Α
RCS				CMS	INIT:ALIZATION PASS	CHEM-COCH TRIM	1 ENGINE		L C	€	Ш.	Ц.	11	Ш	11	11	1	↓↓	Α.	E	Ц_	Ļ.
	1		1	PRETHRUST	'~~~	CLOSED-LOOP TRIM	l		C	C	<u> </u>	$\Box$		Ш	Ш	Ш	11	Ш.	В	1	Ш	A
				LATER PASSES			(3)	C	C	A	Ш	Ш	1 4	$\perp$	1	<b>↓</b> ↓	Ш.	[1]	[1]	Ш	В	
			ACCELERATION					(2)	(6)	(4)	D	Ш	Ш	B	Ш	11	Ш	$oxed{\bot}$		<u> </u>		Ц
	ļ '	MANUAL	PULSE					(2)	$\Pi$	$\Box$	0	Ш	Ш	C	Ш	Ш.	Ш	Ц.,	ᆜᆜ	┦		Ш
		j	DISCRETE					{2}	Ш	Ш.	C	ш	Ш	1.4	11	Ц.	11-	<u> </u>	Ц.	<del>                                     </del>	<del>∐</del>	Н
		AUTO						c	Ш	$\bot$	(2)	Ш	11	A	11	44-	11	1	╀┵	<del> - -</del>	₩.	<b></b>
	TRANS-		ACCELERAT	TION				A	Ш		[3]	1.	╙	(4)	11	Ш.	11	Щ.	110	닏	1	ш
	J. HOR	MANUAL	PULSE					В	(4)	{41	[3]	A	A	(4)	A	(1)	(1)	(1)	(11	(11	В	8

NOTES: 1. NOT APPLICABLE

2. A UK #

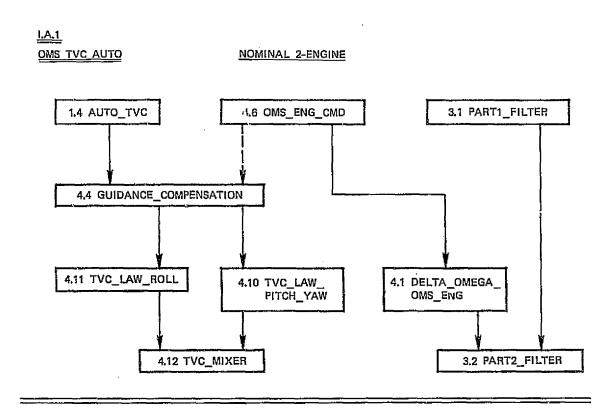
3. C OR I

4. ALL POSITIONS COMPATIBLE

#### OFC MODES AND SUBMODES

I. TVC	A. AUTO	<ol> <li>Nominal 2-Engine, No Failure</li> <li>Failure Detection, No Failure Id'n         <ul> <li>First Pass</li> <li>Subsequent Pass</li> </ul> </li> <li>RCS Assist - Roll Only</li> <li>RCS Assist - Roll and P/Y         <ul> <li>Not Latched and Time &gt; TBD</li> <li>Latched or Time &lt; TBD</li> </ul> </li> </ol>
	B. MANL	14. (Same as above)
II. RCS ROTATION	A. AUTO	1. Two Axis Att Mnvr  2. Three Axis Att Mnvr  3. Barbeque  4. Attitude Local Vertical  5. Payload Attitude  6. Misc Tracking  7. OMS Prethrust  a. First Pass  1) Open Loop Trim  a) 2-Engine (1) Maneuver (2) Attitude Hold  b) 1-Engine (1) Maneuver (2) Attitude Hold  2) Closed Loop Trim  a) Maneuver
		b) Attitude Hold b. Subsequent Pass 1) Maneuver 2) Attitude Hold
	B. MANL	1. Two Axis a. No Att Hold (= Free Drift) 1) Accel (all axes) 2) Pulse (all axes) 3) Mixed Accel and Pulse b. Att Hold (Disc, all axes) c. Mixed Modes, axis by axis 27. (Same as above)
III. RCS TRANS-	A. AUTO	
LATION	B. MANL	1. Accel, Accel 2. Pulse, Pulse 3. Accel, Pulse 4. Pulse, Accel

Figure 4.2.1.1-2. OFC control law function module sequencing requirements (page 1 of 21).



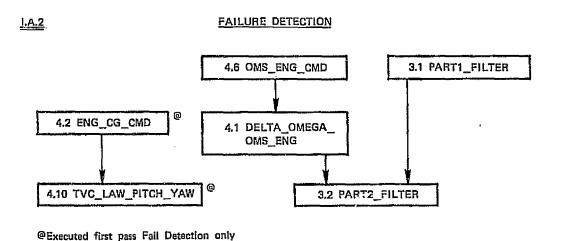


Figure 4.2.1.1-2. OFC control law function module sequencing requirements (page 2 of 21).

# <u>I.A.3</u>

# TVC AUTO

RCS ASSIST\_ROLL ONLY

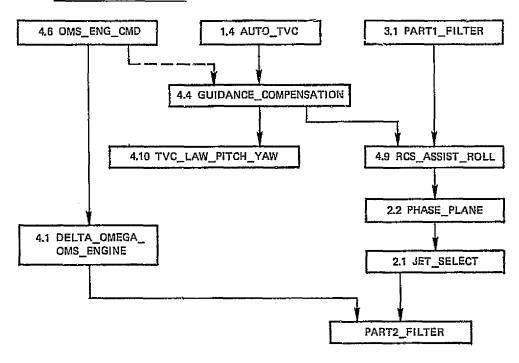


Figure 4.2.1.1-2. OFC control law function module sequencing requirements (page 3 of 21).

# 1,A,4,a

#### TVC AUTO

# RCS ASSIST (FAILURE ID'N)

ROLL ASSIST & P/Y ASSIST (UNLATCHED, ASSIST\_TIMER > TBD)

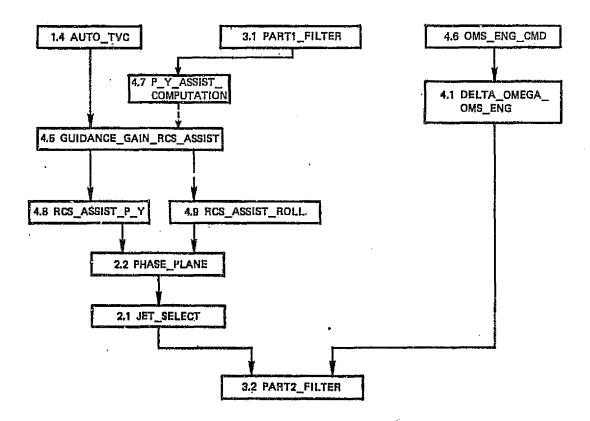


Figure 4.2.1.1-2. OFC control law function module sequencing requirements (page 4 of 21).

# <u>1.А.4.Ь</u>

#### TVC AUTO

# RCS ASSIST (FAILURE ID'N)

- . ROLL ASSIST & P/Y ASSIST-
- ⇒ LATCHED OR ASSIST\_TIMER < TBD

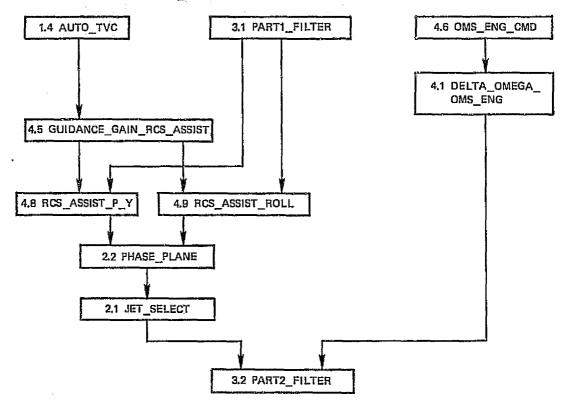
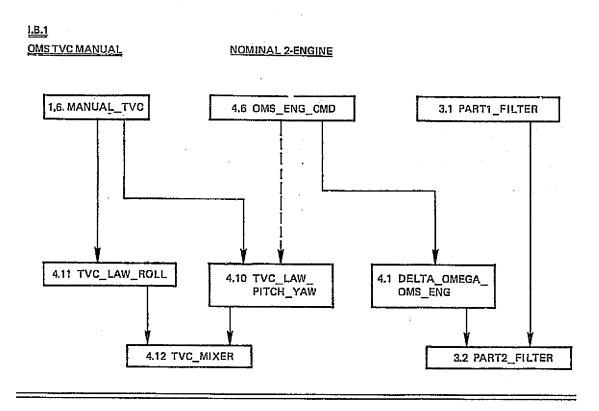


Figure 4.2.1.1-2. OFC control law function module sequencing requirements (page 5 of 21).



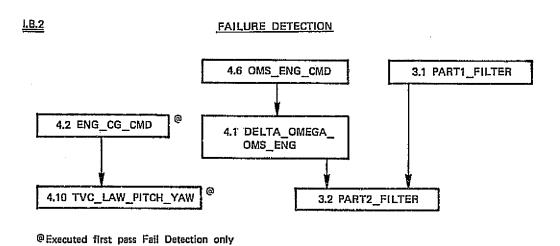


Figure 4.2.1.1-2. OFC control law function module sequencing requirements (page 6 of 21).

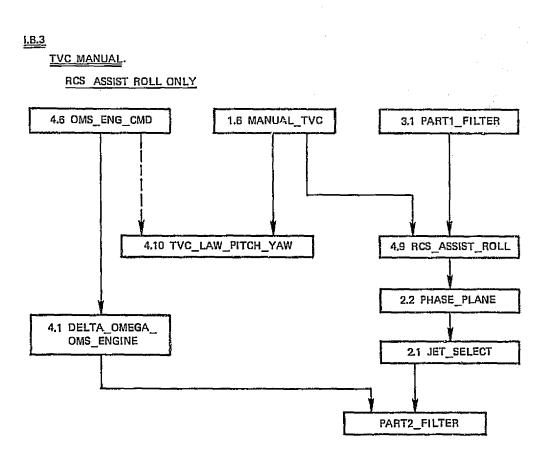


Figure 4.2.1.1-2. OFC control law function module sequencing requirements (page 7 of 21).

#### 1. ...a

#### TVC MANUAL

#### RCS ASSIST (FAILURE ID'N)

ROLL ASSIST & P/Y ASSIST (UNLATCHED, ASSIST\_TIMER > TBD)

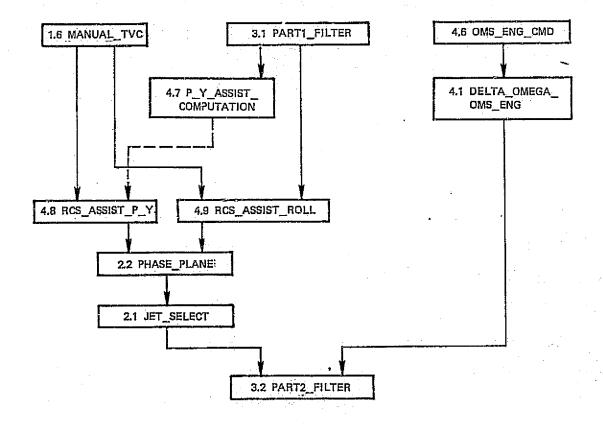


Figure 4.2.1.1-2. OFC control law function module sequencing requirements (page 8 of 21).

#### I.B.4.b

#### TVC MANUAL

#### RCS ASSIST (FAILURE ID'N)

- ROLL ASSIST & P/Y ASSIST
- LATCHED OR ASSIST\_TIMER < TBD

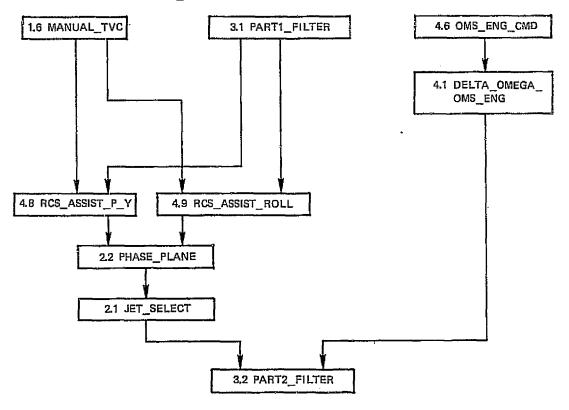


Figure 4.2.1.1-2. OFC control law function module sequencing requirements (page 9 of 21).

#### II.A.1 through II.A.6, case a



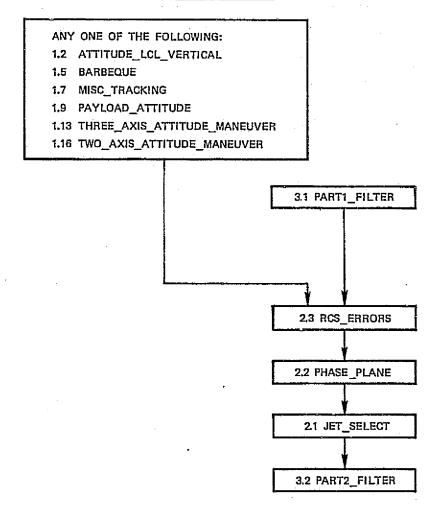


Figure 4.2.1.1-2. OFC control law function module sequencing requirements (page 10 of 21).

#### II.A.1 through II.A.6, case b

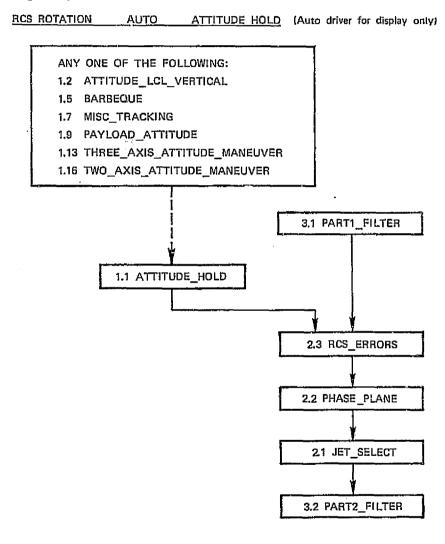


Figure 4.2.1.1-2. OFC control law function module sequencing requirements (page 11 of 21).

II.A.7,a.1,a.1 OMS\_P\_T; FIRST\_PASS; OPEN LOOP TRIM; NO ATT HOLD; TWO ENGINES

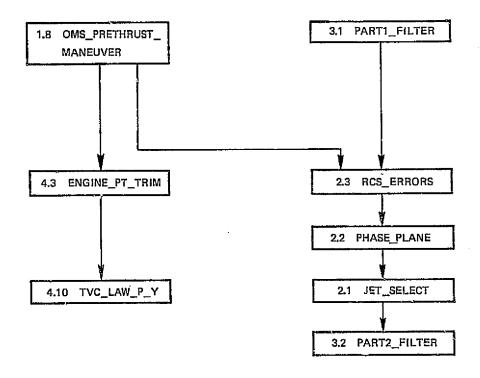


Figure 4.2.1.1-2. OFC control law function module sequencing requirements (page 12 of 21).

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II.A.7.a.1.a.2 OMS\_P\_T; FIRST\_PASS; OPEN LOOP TRIM; ATT HOLD; TWO ENGINES (OMS\_PRETHRUST\_MANEUVER FOR DISPLAY AND OMS ENGINE TRIM ONLY)

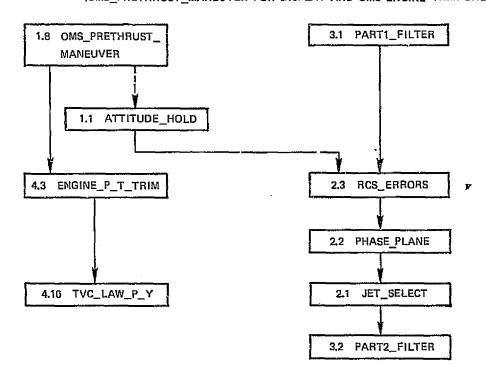


Figure 4.2.1.1-2. OFC control law function module sequencing requirements (page 13 of 21).

II.A.7.a.1.b.1 OMS\_P\_T; FIRST\_PASS; OPEN LOOP TRIM; NO ATT HOLD; ONE ENGINE

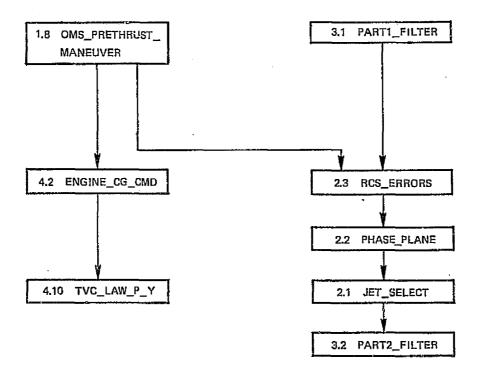


Figure 4.2.1.1-2. OFC control law function module sequencing requirements (page 14 of 21).

II.A.7.a.1,b.2 OMS\_P\_T; FIRST PASS; OPEN LOOP TRIM; ATT HOLD; ONE ENGINE (OMS\_PRETHRUST\_MANEUVER FOR DISPLAY AND OMS ENGINE TRIM ONLY)

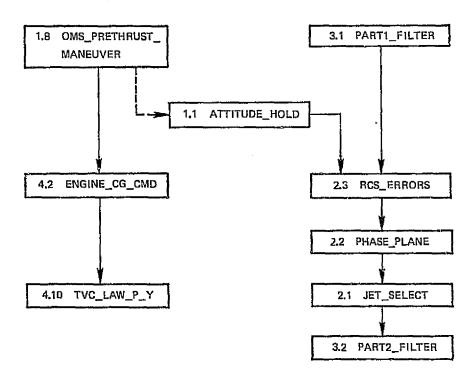
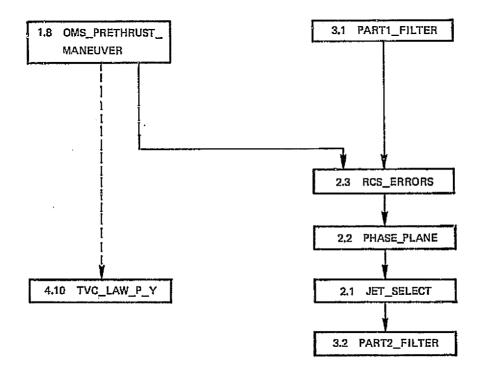


Figure 4.2.1.1-2. OFC control law function module sequencing requirements (page 15 of 21).

II.A.7.a.2.a OMS\_P\_T; FIRST\_PASS; CLOSED LOOP TRIM; NO ATT HOLD



. Figure 4.2.1.1-2. OFC control law function module sequencing requirements (page 16 of 21).

II.A.7.a.2b OMS\_P\_T; FIRST\_PASS; CLOSED LOOP TRIM; ATT HOLD (OMS\_PRETHRUST\_MANEUVER FOR DISPLAY AND OMS ENGINE TRIM ONLY)

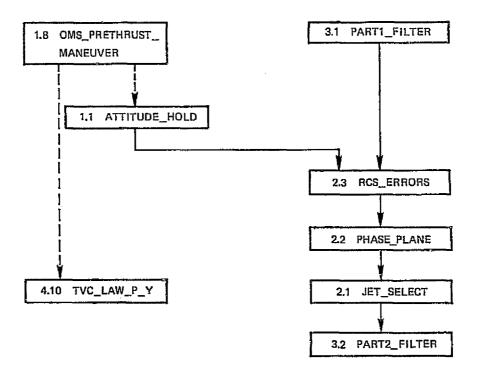


Figure 4.2.1.1-2. OFC control law function module sequencing requirements (page 17 of 21).

II.A.7,b.1 OMS\_P\_T; > FIRST\_PASS; NO ATT HOLD

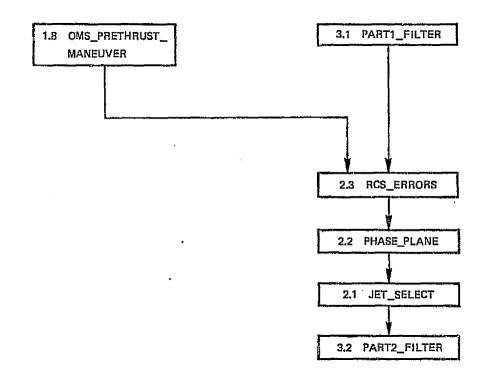


Figure 4.2.1.1-2. OFC control law function module sequencing requirements (page 18 of 21).

II.A.7.b.2 OMS\_P\_T; > FIRST\_PASS; ATT HOLD (OMS\_PRETHRUST\_MANEUVER FOR DISPLAY ONLY)

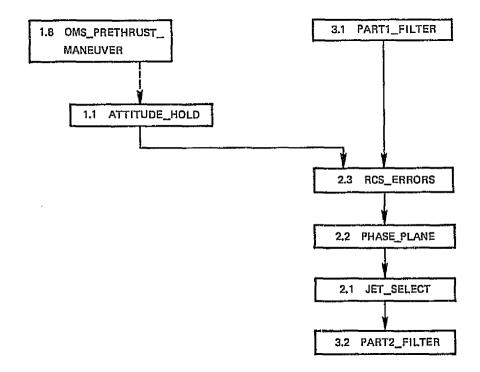


Figure 4.2.1.1-2. OFC control law function module sequencing requirements (page 19 of 21).

II.B
RCS ROTATION:MANUAL (OPTIONAL AUTO DRIVER FOR DISPLAY ONLY)

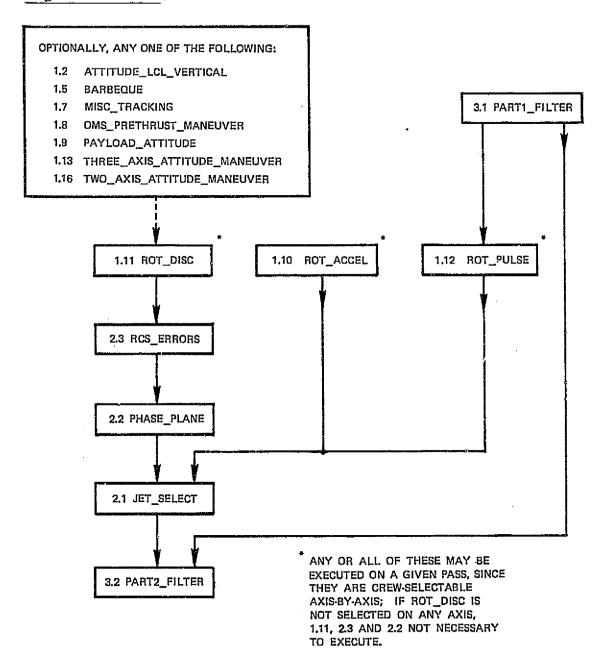
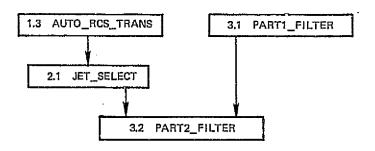


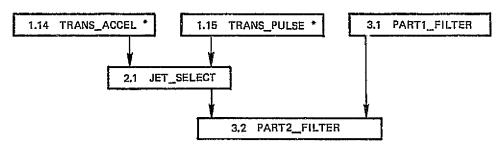
Figure 4.2.1.1-2. OFC control law function module sequencing requirements (page 20 of 21).

### III.A. RCS TRANSLATION\_AUTO



#### III.B. RCS TRANSLATION\_MANUAL

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EITHER OR BOTH OF THESE MODULES MAY BE EXECUTED IN A GIVEN CYCLE, BECAUSE THEY ARE SELECTABLE AXIS-BY-AXIS BY THE FLIGHT CREW.

Figure 4.2.1.1-2. OFC control law function module sequencing requirements (page 21 of 21).

# 4.2.1.2 Processing Rate OFC RECON is processed at 25 Hz.

#### 4.2.1.3 Interface Requirements

The interface requirements of OFC\_RECON are given in Table 4.2.1.3-1.

#### 4.2.1.4 Control Law Function Module Initialization

Table 4.2.1.4-1 lists the conditions for initializing the control law modules. The modes, submodes and conditions are the same as those of Table 4.2.1.1-2 with the following exceptions:

- First pass/restart is any entry into OFC\_RECON with the OFC RESTART flag set.
- 2) TVC fail-detect is the presence of OMS\_FAIL\_DETECT during TVC mode, regardless of whether an identification (OMS1\_FAIL or OMS2 FAIL) is present.

The behavior of the individual control law function modules upon initialization is described in subsections 4.2.2.1 through 4.2.2.4.

TABLE 4.2.1.3-1 OFC\_RECON INTERPACE REQUIREMENTS

HAHE	DESCRIPTION	SOURCE OR DESTINATION	TYPE	I     RANGE	UNIT	SAMPLE (H7)
Inputs				!	!	!
RCS_ROTATION	RCS rotation mode enable   (1=enable)	i HSC	B	10,1	Inone	25
RCS_AUTC_MAHUAL	RCS auto/manual select (1=auto;   0=manual)	INSC	I B	10,1	I none	(25
ATT_HNVR	[Auto RCS rotation mode select [(1=maneuver: two axis, three [axis, OMS prethrust, local [vertical, rayload, tracking or [barbeque; 0=hold)	HSC	[B	[0,1	none	25         
FRO_AXIS	(Two axis maneuver enable (1=enable)	i HSC	B !	10,1	none	15/6
THREE_AXIS	Three axis maneuver enable   (1=enable)	HSC	B	10,1	(none	15/6 1
oks_prethrust	ONS prethrust maneuver enable   (1=enable)	∄ MSC 1	B	10,1	none	15/6
LCL_YERT_ATT	[Local maneuver enable (1=enable)	IRSC	В	10,1	Inone	5/6
PAYLD_SUP_CHDS	Payload Supplied commands  waneuvers enable (1=enable)	I BSC	I B	10,1	I none	15/6
TRACKING	[Tracking maneuver enable   (1=enable)	( HSC	[ B	10,1	none	15/6
3BQ	Barbecue maneuver enable   (1=enable)	INSC	B	10,1	! none	15/6
CS_TRANSLATION	RCS translation mcde enable   (1=enable)	l asc	B	10,1	I none	25
DHS_ARH_REQ	OMS engines arming request   (1=request)	MSC	[ A (2) B	10,1	l none	125
ES_ON_REQ	OMS engines turn-on request  (1=request)	I MSC	IA (2) B	10,1	none	125 1

TABLE 4.2.1.3-1 OFC\_RECON INTERFACE REQUIREMENTS

NAME	DESCRIFIION	SOURCE OF DESTINATION	i I TYPE	   RANGE	I I I UNIT I	SAMPLF   BATF (H7)
	TVC auto/manual select (1=auto; 0=manual)	I NSC	B	10,1	none	125
IK	OMS gimbal trim value select (1=closed loop: use value remaining from previous OMS burn; 0=open loop: use value computed from expected cg location)	NSC    -  -	{ B	10,1	Inone	1/maneuver         
	OFC module initialization flag (1=init)	MSC, OFC_RECON	B	10,1	Inone	125
_	To burn/not to burn status of OHS engines (1=to burn; 0=not to burn)	I DEC	A (2) B	10,1	none	!1/maneuver
OHS_FAIL_DETECT	OBS failure detected (1=detected)	l HH	I B	16,1	none	125
OHS1_FAIL	CBS1 failure identified (1=identified)	RB	ļB ļ	10,1	[none	125
	CMS2 failure Identified (1=identified)	BH	¦B	[0,1	Inone	125 !
		PANEL_SWITCH_INTERP, GPC_RECON	(A(3)I	1,2,3	none	125
	Manual translation submode select (1=accel; 2=pulse)	PANEL_SWITCH_INTERP	A (3) I	11,2	Inone	125
	RCS nominal/vernier jet select (1=nominal; 0=vernier)	PAHEL_SWITCH_INTERP, OFC_RECON	(A (3) B	10,1	none	125
	Rctational hand controller command	HHC_READ	in (3) T	-1,0,1 	none	125
i -	Flag indicating retational hand centreller is deflected beyond soft stop (1=beyond softstop)	RHC_READ	( A ( 3 ) B	  0,1	none	25   
ONS1_ON_CHD	OHS1 engine or command (1=on)	ONS_ENG_CMD	†B	10,1	Inone	25

TABLE 4.2.1.3-1 OFC\_RECON INTERFACE REQUIREMENTS

NAKE	DESCRIPTION	SOURCE OR DESTINATION	TYPE	   HANGE 	UNIT	SAMPLE   PATE (HZ)
CH52_OH_CHD	OMS2 engine on command (1=on)	OHS_ENG_CHD	B	Ţ0,1	none	125
_ "	Flag requesting RCS assistance of TVC for pitch and yaw control (1=request)	PITCH_YAW_ASSIST, COMPUTATION, OFC_RECON	I В   В	10,1	none	125
AXIS	Body axis for this execution	OFC_RECON	į ĮI	11,2,3	Inone	25/axis
	Non-execution command, by axis   (1=do not execute)	OFC_RECON	A (3) B	10,1	none	125
INIT_ONS_PRETHRUST NANEUVER		OFC_RECON	В	10,1	none	25   
Outputs	<u> </u>	<u> </u>	 	<del></del>		
INIT_AUTO_RCS_TRANS		AUTO_RCS_TRANS	B 	10,1	Inone	125
		TWO_AXIS_ATTITUDE_HA-   NEUVER	[ B	10,1	none	15/6
	Hodule initialization flag   (1=initialization)	THREE_AXIS_ATTITUDE	B   	10,1	inone	5/6 
	Module initialization flag   (1=initialization)	ONS_PRETHRUST_HANEUV-	1 B	0,1	none	15/6 !
INIT_ROT_PULSE	Hodule initialization flag   (1=initialization)	ROT_PULSE	(A (3) B	10,1	none	125
		TBANS_PULSE	A (3) B	10,1	Inone	125
	Module initialization flag   (1=initialization)	ROT_DISC	B   B	10,1	Inone	125
	Hodule initialization flag   (1=initialization)	ATTITUDE_LCL_VERTICAL	B   B	0 , 1	none	15/6 I

TABLE 4.2.1.3-1 OFC\_BECON INTERFACE REQUIREMENTS

NAME	DESCRIFTION	SOUPCE OR DESTINATION	!     TYPE	   RANGE	l     UNIT 	SAMPLE   SAMPLE   RATE (HZ)
INIT_BARBEQUE	Mcdule initialization flag   (1=initialization)	BARBEQUE	B	[3,1	none	15/6
INIT_ATTITUDE_HCLD	Module initialization flag   (1=initialization)	ATTITUDE_HOLD	B 	10,1	none 	[25
INIT_HANUAL_TVC	Module initialization flag   (1=initialization)	HANUAL_TVC	l   B 	10,1	(none	(25
INIT_RCS_ERRORS	Hodule initialization flag   (1=initialization)	RCS_ERRORS	l B   B	10,1	none	125
INIT_PHASE_FLANE	Module initialization flag   (1=initialization)	(PHASE_PLANE	l B	10,1	Inone	[25
INIT_JET_SELECT		JET_SELECT	IB	10,1	none	125
INIT_PART1_FILTER		PART1_FILTER	B	10,1	(none	125
INIT_GUIDANCE_COMPE- PSATION	Rodule initialization flag   (1=initialization)	GUIDANCE_COMPENSATION	B	10,1	none	[25
	Hodule initialization flag   (1=initialization)	CHS_ENG_CMD	B	10,1	none	[25
	Hodule initialization flag   (1=initialization)	PITCH_YAW_ASSIST_COM-	B 	13,1	none	125
INIT_RCS_ASSIST_BOLL	Module initialization tlag   (1=initialization)	RCS_ASSIST_ROLL	1   B 	10,1	inone	125
	Hodule initialization flag	IRCS_ASSIST_PITCH_YAW	! <u></u> ( В	10,1	Inone	125
	Module in/tialization flag   (3=initialization)	TVC_LAW_FOLL	<u>                                     </u>	13,1	1000 e	125
			L			

TABLE 4.2.1.3-1 OFC\_RECON INTERFACE REQUIREMENTS

NAME	i i description	SOURCE OR DESTINATION	TYPE	I I FANGI	I I I UNIT	SAMPLE   SAMPLE   RATE (HZ)
YAW	Module initialization flag (0=no linit; 1 =closed lcop init using trim value remaining from previous OBS burn; 2=open loop linit using trim value computed from expected cg location)	TYC_LAW_PITCH_YAW    -  -  -	II	10,1,2	none         	; 25 
	OFC module initialization flag   (1=init)	HSC, OFC_RECON	B 	10,1	none	25 
ROT_OPTION	Manual rotation submode select   (1=accel; 2=pulse; 3=discrete)	PAHEL_SWITCH_INTERP, OFC_RECON	A (3) I	11,2,3	none	125
BOT_HI_LO_SW	Rotational acceleration level  select (1=high; 0=lov)	PANEL_SWITCH_INTERP, JET_SELECT	A (3) B	10,1	none	1/maneuver
	Translational acceleration level  select (1=high; 0=low)	PANEL_SWITCH_INTERP,  JPT_SELECT	A (3) B	10,1	none	1/maneuver
NON_VERNIER_SW	RCS nominal/vernier jet select   (1=nominal: 0=wc_nier	PANEL_SWITCH_INTERP,   JET_SELECT, OFC_RECON		10,1	none	[25 
OBS1_PITCH_YAW_CHD	OMS1 engine pitch and yaw commands	SOP, RM	A (2) 5	T'BD	deg	1/maneuver
	OMS2 engine pitch and yaw   commands	SOP, RM	A (2) S	TBD	i deg	1/maneuver
AXIS		ROT_ACCEL, ROT_PULSE, TRANS_ACCEL, TRANS_PULSE, OFC_RECON		11,2,3	I none	25/axis
BYEASS		ROT_DISC,  PHASE_PLANE,  OFC_RECON	A (3) B	10,1	none	25 
BOT_JET_CHD	Rotation command	JET_SELECT,   PHASE_PLANE	A (3) I	1-1,3,1	none	125
TBANS_JET_CHD	Translation command	JET_SELECT	A (3) I	1-1,0,1	Inone	125

TABLE 4.2.1.3-1 OFC\_RECON INTERFACE REQUIREMENTS

na He	I I DESCRIPTION	I SOURCE OR I DESTINATION	TYPF	     FANGE 	1   UNIT   L	SAMPLE   FATE (HZ)
ATTITUDE_GAIH1	Filter 1 gain for attitude term	PART 1_PILTER	5	TBD	none	[1/maneuver
ATTITUDE_GAIN2	Filter 2 gain for attitude term	PARTI_FILTER	5	TEE	Trous	1/maneuver
RATE_GAIN1	Filter 1 gain for rate term	PART1_FILTER	L	TED	l none	1/maneuver
RATE_GAIN2	Filter 2 gain for rate term	PART 1_FILTER	5	TBD	I none	1/maneuver
ACCEL_GAIN	Filter 2 gain for acceleration	PART1_FILTER	   \$ 	TPD	Inone	1/maneuver
	Flag indicating number of OBS  engines to burn  (1 = 1 engine; 2 = 2 engines)	TVC_LAW_PITCH_YAW	   	11,2	I none	25 
GUID_COMP_GAIN	TYC compensation gains	GUIDANCE_COMPENSATION	A (3) S	TBO	none	125
ASSIST_PITCH_YAW	Flag requesting RCS assistance of  TYC for pitch and yaw control  {1=request}	OFC_RECON	В   	10,1 1	[none	125

Table 4.2.1.4-1. Control law function module initialization conditions.

INITIALIZATION FLAG	SET FLAG ON ENTRY INTO SPECIFIED MODE, SUBMODE, CONDITION
INIT_AUTO_RCS_TRANS	RCS translation auto
INIT_TWO_AXIS_ATTITUDE_MANEUVER	RCS two-axis*
INIT_THREE_AXIS_ATTITUDE_MNVR	RCS three-axis*
INIT_OMS_PRETHRUST_MANEUVER	RCS OMS-prethrust*
INIT_ROT_PULSE	RCS rotation manual pulse (by axis)
INIT_TRANS_PULSE	RCS translation manual pulse (by axis)
INIT_ROT_DISC	RCS rotation manual discrete (each axis)
INIT_ATTITUDE_LCL_VERTICAL	RCS local-vertical*
INIT_BARBEQUE	RCS barbeque*
INIT_ATTITUDE_HOLD	RCS rotation auto attitude-hold
INIT_MANUAL_TVC	TVC manual
INIT_RCS_ERRORS	First pass/restart
INIT_PHASE_PLANE	RCS or TVC
INIT_JET_SELECT	RCS or TVC
INIT_PART1_FILTER	First pass/restart
INIT_GUIDANCE_COMPENSATION	TVC auto
INIT_OMS_ENG_CMD	First pass/restart
INIT_PITCH_YAW_ASSIST_COMPUTATN	TVC
INIT_RCS_ASSIST_ROLL	TVC
INIT_RCS_ASSIST_PITCH_YAW	TVC RCS-assist-roll-pitch-yaw
INIT_TVC_LAW_ROLL	TVC
INIT_TVC_LAW_PITCH_YAW	RCS OMS-prethrust* closed-loop-trim (flag=1)
	RCS OMS-prethrust* open-loop-trim or TVC fail-detect (flag=2)

<sup>\*</sup>These drivers may be called for display purposes without the necessity of performing the maneuver by enabling the rotation, automatic and attitude-maneuver submodes. Calling OMS PRETHRUST MANEUVER will cause OMS engine trimming in addition to generating display outputs.

#### 4.2.2 Control Law Module

Figure 4.2.2-1 is the major block diagram of the On-Orbit FC control law module. This module contains 33 function modules which execute the control laws. On any given pass, the configuration of the control law module, i.e., the effective interconnection of the function modules, is determined by inputs from the supervisory module OFC\_RECON and from external sources including RM, MSC, D&C, RHC\_READ and PANEL\_SWITCH\_INTERP.

Configuration control is implemented in four ways:

- 1) By executing the particular function modules necessary to perform a given task in the sequence required. This function is performed by OFC\_RECON and indicated in Figure 4.2.2-1 by switches S1 through S15, whose logic is described in Section 4.2.1.1.
- 2) By passing initialization flags to the function modules which in turn initialize pass-to-pass storage elements such as filters, counters and integrators. All initialization flags are generated by OFC\_RECON.
- 3) By passing parameters defining quantitative behavior of certain function modules. These parameters include gains, magnitudes, thresholds and deadbands, and are supplied by OFC RECON and external sources.
- 4) By directly "forcing" certain variables. OFC\_RECON does this when making major mode changes.

The control law function modules are grouped into four categories: Drivers, RCS DAP, TVC DAP, and State Estimator. The general sequence of processing is:

- 1) State Estimator, part 1
- 2) Driver(s)
- 3) DAP(s)
- 4) State Estimator, part 2

The State Estimator combines IMU attitude measurement data with extrapolations based on effector commands, to form a filtered estimate of the vehicle angular state. To reduce transport lag, the process is divided into two parts. Part 1 performs only those portions of the estimation function which are necessary to develop the effector commands.

These include incorporation of IMU data and development of vehicle angular rate and undesired angular acceleration data. Part 2 of the State Estimator performs the remainder of the estimation function, chiefly the extrapolations, after the DAP(s) have issued the effector commands.

The Drivers convert a variety of input commands and data to forms acceptable by the respective DAPs. Reading from top to bottom in Figure 4.2.2-1, the 16 drivers are divided into the following types:

- 1) 2 manual RCS translation
- 2) l automatic RCS translation
- 3) 7 automatic RCS rotation: attitude maneuver
- 4) 1 automatic RCS rotation: attitude hold
- 5) 3 manual RCS rotation
- 6) 1 manual TVC
- 7) l automatic TVC

The RCS translation drivers generate commands for the jet selection module in the RCS DAP. The two manual RCS translation drivers process a single vehicle axis at a time, while the automatic RCS translation driver is a three-axis routine.

Of the RCS rotation drivers, all but two generate commands for the RCS DAP error determination module; the remaining two (ROT\_ACCEL\_ and ROT\_PULSE) drive the jet selection routine directly. The seven attitude maneuver drivers additionally supply display data expressing desired vehicle attitude as IMU gimbal angles, and five of these provide a flag for display indicating completion of a maneuver. It is possible to display the outputs of any of the attitude maneuver drivers while actually controlling RCS rotation with attitude hold or manual RCS rotation drivers. All the automatic RCS rotation drivers operate on three vehicle axes. The manual RCS rotation drivers may be selected axis by axis. Two of these, ROT ACCEL and ROT PULSE, are in fact singleaxis processors. ROT DISC is somewhat hybrid, combining single-axis and three-axis attributes. It is basically a three-axis routine, since it must supply a complete set of desired IMU gimbal angle increments to the RCS DAP; however, it is operated such that any one, two or three axes can be processed while components about nonparticipating axes are zeroed. Although this causes spurious error components to be generated (assuming that ROT ACCEL and/or ROT PULSE are producing rotations about axes not using ROT\_DISC), these components are never acted upon since the phase plane switching logic reads the same variable, BYPASS, that ROT DISC does in determining which axes to process.

Each of the TVC drivers provides a three-axis body rate command to the TVC DAP.

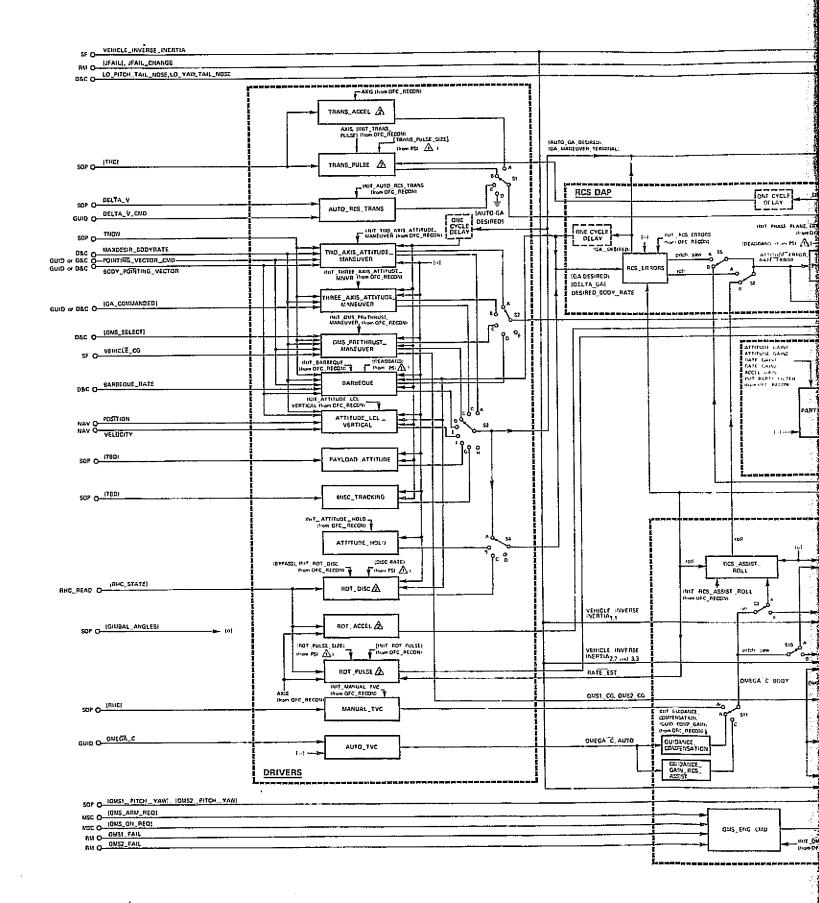
The RCS DAP consists of jet selection logic preceded by a "front end" for rotation only, which obtains attitude and angular rate errors, and processes these through a phase plane switching logic that drives the vehicle into a limit cycle about the desired attitude and angular rate. No preprocessing is used for the translation commands, which come directly from the drivers to the jet selection logic; two rotation drivers also feed commands directly to the jet selection logic. In addition to producing the primary RCS DAP output—commands to the RCS jets—the jet selection logic also provides translational and rotational velocity change predictions for use respectively by TRANS\_PULSE and part 2 of the State Estimator. During TVC operation, the RCS DAP may be called upon to assist the TVC DAP in controlling vehicle attitude. When this happens, error signals from the TVC DAP drive the phase plane switching logic, and thus the selected TVC driver is in control of both DAPs.

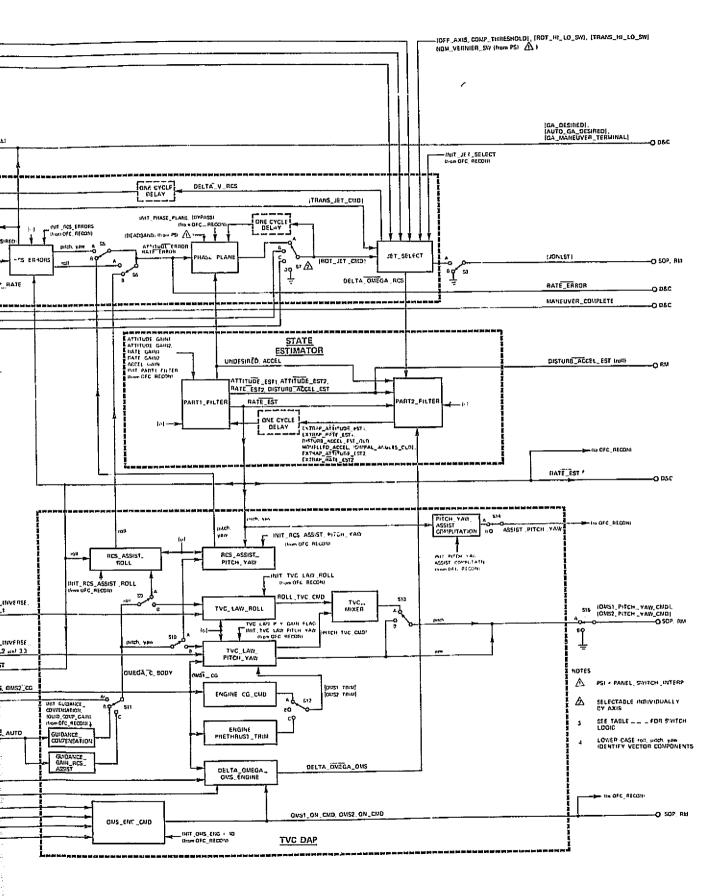
The TVC DAP contains all the functions required for on-off and thrust vector control of the OMS engines, and provides extrapolation data to the State Estimator. When only one OMS engine is operating, the TVC DAP needs RCS DAP assistance for roll control, and may need it for pitch and yaw control; the TVC DAP must then additionally supply error data to the RCS DAP and calculate whether or not RCS assistance is needed in pitch and yaw. Because pitch and yaw may be controlled differently from roll, the TVC law function and the RCS assist error-determination function are each split into two modules to prevent execution of unnecessary code.

The starting or trim orientations of the OMS engines are calculated and commanded both before an OMS burn and at the time of an engine failure during a two-engine burn. The one-engine trim value has each engine pointed to thrust through the vehicle cg, and the two-engine value has both engines parallel, with the total thrust through the cg. A third choice of trim exists after an OMS burn has taken place: the trim value stored in the TVC law function, which has had the benefit of thrust misalignment correction, can be used as the starting trim for the next burn.

The control law function modules are described in Sections 4.2.2.1 through 4.2.2.5. Within these sections, the modules are ordered alphanumerically by name. The groupings are as follows:

Section	Subject
4.2.2.1	Driver modules
4.2.2.2	RCS DAP modules
4.2.2.3	State Estimator modules
4.2.2.4	TVC DAP modules
4.2.2.5	Service modules (referred to in Sections 4.2.2.1
	through 4.2.2.4)





#### 4.2.2.1. Drivers

## 4.2.2.1.1 ATTITUDE\_HOLD

- A. <u>Function</u>: This module provides inputs to the RCS DAP to effect a three-axis attitude hold. The vehicle is held to the attitude it had at the time of selection of the attitude hold submode, and will return to that attitude if it has a nonzero angular rate when the selection is made.
- B. Block Diagram: Figure 4.2.2.1.1-1
- C. Processing Rate: TBD
- D. <u>Interface Requirements</u>: Table 4.2.2.1.1-1
- E. Constants: none
- F. Initialization Requirements: Table 4.2.2.1.1-2

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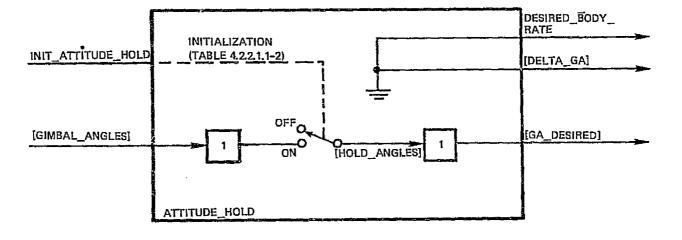


Figure 4.2.2.1.1-1. ATTITUDE\_HOLD.

TABLE 4.2.2.2.1.1-1 ATTITUDE\_HOLD INTERFACE REQUIREMENTS

KAHE	DESCRIPTION	SOURCE OR DESTINATION	1     TYPE 	   BANGE	I I I UNIT	SAMPLE   RATE (HZ)
Inputs	1	!		Ī	]	
GINBAL_ANGIES	IMV gimbal angles	SOP	A (3) S	[-180 < x [<= 180	deg	1/maneuver
INIT_ATTITUDE_HOLD	Module initialization flag	OFC_RECON	1 B	10,1	none	TBD
Outputs	<u> </u>	<u> </u>		!	!	
DELTA_GA	Desired IMU gimbal angle  increments	RCS_ERROLS	IA (3) S	TPD	<u>  deq</u>   deq	(T9D
DESIRET_BODY_RATE	Desired body angular rate	BCS_ERRORS	i v (3) s	TRD	ldeg/s	TBD
GA_DESIRED	Desired IMU gimbal angles	D&C, RCS_ERRORS	I A (3) S	-180 < x  <= 180	i deg	TBD 

TABLE 4.2.2.1.1-2 ATTITUDE\_HOLD INITIALIZATION REQUIREMENTS

INITIALIZE ON TRANSITION FROM	I INITIALIZE ON TRANSITION TO	VARIABLE	INITIAL VALUE	1111
[INIT_ATTITUDE_HOLD = OFF	INIT_ATTITUDE_HOLD = ON	HOLD_ANGLES	GIMPAI_ANGLPS	ĩ

#### 4.2.2.1.2 ATTITUDE\_LCL\_VERTICAL

- A. <u>Function</u>: This module provides inputs to the RCS DAP to maintain a specified body-axis vector aligned to the local vertical, with zero rotational rate about the specified vector.
- B. Block Diagram: Figure 4.2.2.1.2-1
- C. Processing Rate: 5/6 Hz
- D. Interface Requirements: Table 4.2.2.1.2-1
- E. Constants: Table 4.2.2.1.2-2
- F. Initialization Requirements: Table 4.2.2.1.2-3

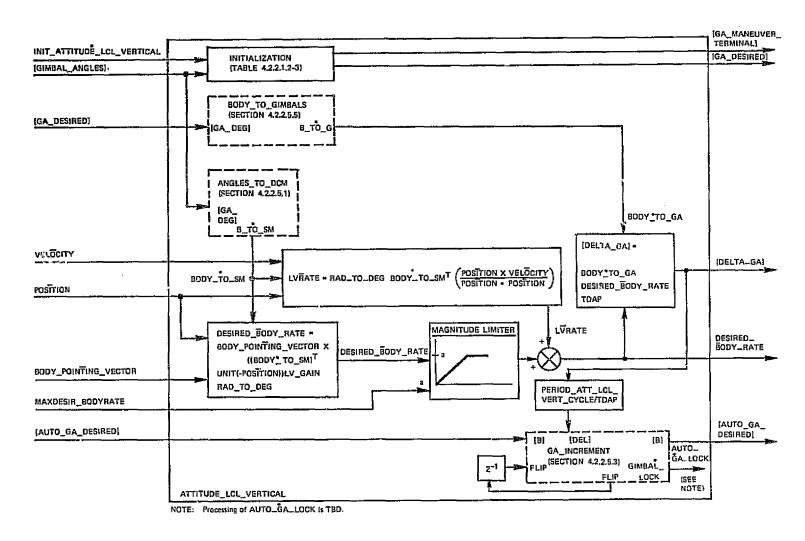


Figure 4.2.2.1.2-1. ATTITUDE\_LCL\_VERTICAL.

TABLE 4.2.2.1.2-1 ATTITUDE\_LCL\_VERTICAL INTERPACE REQUIREMENTS

нане	DESCRIPTION	SOURCE OE DESTINATION	TYPE	I I RANGE	(  -   UNIT 	SAMPLE   BATE (HZ)
Inputs				<u> </u>	   	   
BODY_POINTING_VECTOR	Unit vector, in body axes, to be aligned with respect to local vertical	GUID or D&C	V (3) S	i-1 to +1	none   	5/6   
GINBAL_ANGLES	IMU gimbal angles	SOP	A (3) S	-180 < x  <= 180	deg	15/6
POSITION	(Yehicle position in stable member axes, referred to geocenter	NAV	V (3) S	TBD l	[	15/6
	Yehicle velocity in stable member   axes, referred to geocenter	HAV	V (3) S	TED	f/s 	5/6 
INIT_ATTITODE_LCL_V-	Hodule initialization flag	CPC_RECON	B	10,1	none	15/6
GA_DESIRED	Desired IMU gimbal angles	RCS_ERRORS	A (3) S	(-180 < x (<= 180	deg	15/6
NOTO_GA_DESIRED	Desired IMU gimbal angles	ATTITUDE_LCL_VERTICAL	λ(3)5	[-180 < x  <= 180	đeg	[5/6 ]
BAXDESIR_BODYRATE	Desired maximum hody angular rate	1080	s L	10 to 5	deg/s	[5/6 1
Outputs				<u> </u>	 !	<u> </u>
	Desired IMU gimbal angle increments	RCS_ERRORS	A (3) S	TBD	deg	15/6
DESTREC_BODY_RATE	Desired body augular rate	RCS_ERRORS	V (3) S	TBD	deg/s	15/6
A_DESIRED	Desired INS gimbal angles	DEC, ECS_ERRORS	A (3) S	-183 < x   <= 180	deg I	[1/maneuver
AUTO_GA_DESIRED		D&C, ATTITUDE_LCL_VERTICAL	A (3) S	j-180 < x  <= 180	deg	15/6
SA_HANEUVER_TERMINAL	Desired terminal gimbal angles	DEC	A (3) S	1-180 < x  <= 18€	đea 	1/maneuver
	<u> </u>	<u></u>	L.,,	L	L	

TABLE 4.2.2.1.2-2 ATTITUDE\_LCL\_VERTICAL CONSTANTS

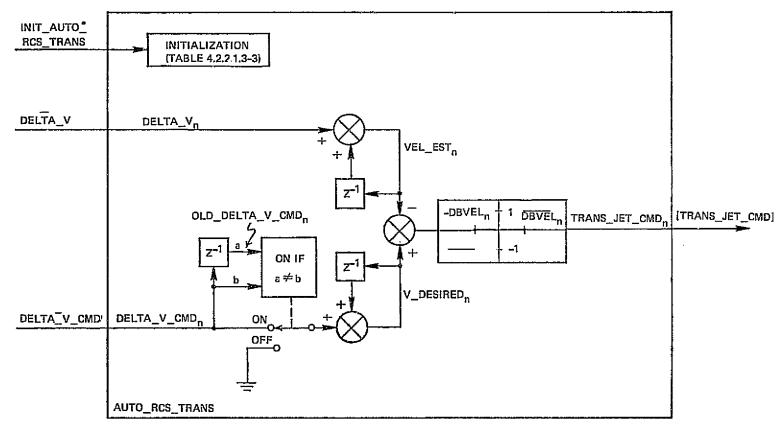
I NAME	DESCRIT	I   TYPE 	VALUF	
ITDAP	(Period of ECS DAP cycle	IS	10.04	ļs į
IPERIOD_ATT_LCL_VERT_CYCLE	Period of ATTITUDE_LCL_VERTICAL cycle	∤S	11.2	s
ILV_GAIN	Attitude error gain	is	(TBD	(deg/s)/deg
PAD_TO_DEG	Radians to degrees conversion factor	IS I	180/pi	deg

TABLE 4.2.2.1.2-3 ATTITUDE\_LCL\_VERTICAL INITIALIZATION FEQUIPFHENTS

INITIALIZE ON TRANSITION FROM	INITIALIZE ON TRANSITION TO	VARIABLE 1 1	INITIAL VALUE
IBIT_ATTITUDE_LCL_VERTICAL =   IOFF   I   I   IOFF   IOF			GINDAL_ANGLES
	[  IHIT_ATTITUDE_LCL_VERTICAL =  ON	   PLIP 	TBD

## 4.2.2.1.3 AUTO\_RCS TRANS

- A. <u>Function</u>: This module provides an input to the RCS DAP to achieve commanded translational velocity changes in three axes. The input command is assumed to differ from its value on the previous pass if and only if it is a new increment; any number of such increments can be commanded in a given maneuver. A velocity error deadband is incorporated to prevent severe cycling.
- B. Block Diagram: Figure 4.2.2.1.3-1
- C. Processing Rate: 25 Hz
- D. Interface Requirements: Table 4.2.2.1.3-1
- E. Constants: Table 4.2.2.1.3-2
- F. Initialization Requirements: Table 4.2.2.1.3-3



NOTE: Array or vector subscript n should be taken as indicating that the processing shown is for one element, and all three elements are processed.

TABLE 4.2.2.1.3-1 AUTO\_RCS\_TRANS INTERFACE REQUIREMENTS

na ne	DESCRIPTION	SOURCE OR DESTINATION	TYPE	   FANGE	i   UNIT	SAMELT   FATE (HZ)
Inputs	[	!	!	Ţ	!	!
DELTA_V_CHD	Commanded translational valocity	{GUID or D&C	V (3) 5	TPD	11/3	1 25
DELTA_V	INU accelerometer data; vehicle   velocity change since previous   sampling	SOP	1 y (3) S	[TBD	f/s 	25 
INIT_AUTO_RCS_TRANS	Bodule initialization flag	CFC_RECON	I B	10,1	none	125
Output	[	!	<u> </u>	!	!	<u> </u>
TRANS_JET_CHD	Translation command	[ JET_SELECT	<u> </u> A (3) I	1-1,0,1	Inone	<u> </u> 25

TABLE 4.2.2.1.3-2 AUTO\_RCS\_TRANS CONSTANTS

NAME	DESCRIPTION	TYPE	VALUF	I UNIT
DEVEL	Velocity error deadband, by axis	[A (3) S	TRD	f/s

I INITIALIZE ON TRANSITION FROM	   INITIALIZE ON TRANSITION   TO	V ARIABLE	INETIAL VALUF
	1 1 1	VEL_EST V_DESIRED OLD_DELTA_V_CMD	G

## 4.2.2.1.4 AUTO\_TVC

- A. <u>Function</u>: This module provides an input to the TVC DAP to achieve a three-axis vehicle angular rate corresponding to a commanded angular rate in inertial coordinates, during a TVC burn.
- B. Block Diagram: Figure 4.2.2.1.4-1
- C. Processing Rate: 2 Hz (tentative)
- D. Interface Requirements: Table 4.2.2.1.4-1
- E. Constants: none
- F. Initialization Requirements: none

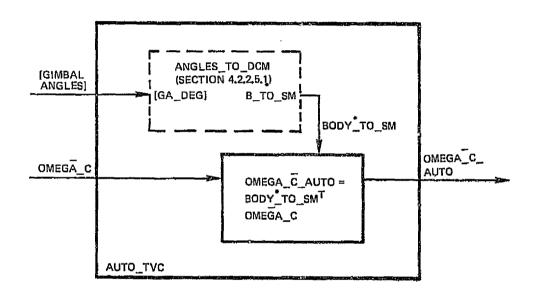


Figure 4.2.2.1.4-1. AUTO\_TVC.

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TABLE 4.2.2.1.4-1 AUTO\_TVC INTERFACE REQUIREMENTS

NAME	 	SOURCE OR DESTINATION	I TYPE	   FANGE	i i i unit	SAMPLE   FATE (HZ)
(Inputs	[			<u> </u>	<u> </u>	<u> </u>
OHEGA_C	Commanded vehicle angular rate in	GUID	7 (3) S	(TED	deg/s	12 
GIMBAL_ANGLES	INU gimbal angles	SOP		-180 < x  < 180	l deg	12 I
Output	!		<u> </u>	!	<u> </u>	!
OHEGA_C_AUTO		GUIDANCE_COMPENSATIO- H, GUIDANCE_GAIN_RCS_AS- SIST	1	TED I	deg/s       	2   1   1

### 4.2.2.1.5 BARBEQUE

- A. Function: This module provides drive signals to the RCS DAP to align a specified body vector to a commanded inertial vector and then rotate the vehicle about the body vector at a predetermined rate. Upon initialization, TWO\_AXIS\_ATTITUDE\_MANEUVER is called to perform the vector alignment maneuver. When the maneuver has proceeded to within a predetermined angular deadband of the terminal attitude, it is abandoned and the rate drive algorithms executed instead. Any maneuver rate components usable by the rate drive are thus preserved. A second initialization is used to implement the changeover.
- B. Block Diagram: Figure 4.2.2.1.5-1
- C. Processing Rate: 5/6 Hz
- D. Interface Requirements: Table 4.2.2.1.5-1
- E. Constants: Table 4.2.2.1.5-2
- F. Initialization Requirements: Table 4.2.2.1.5-3

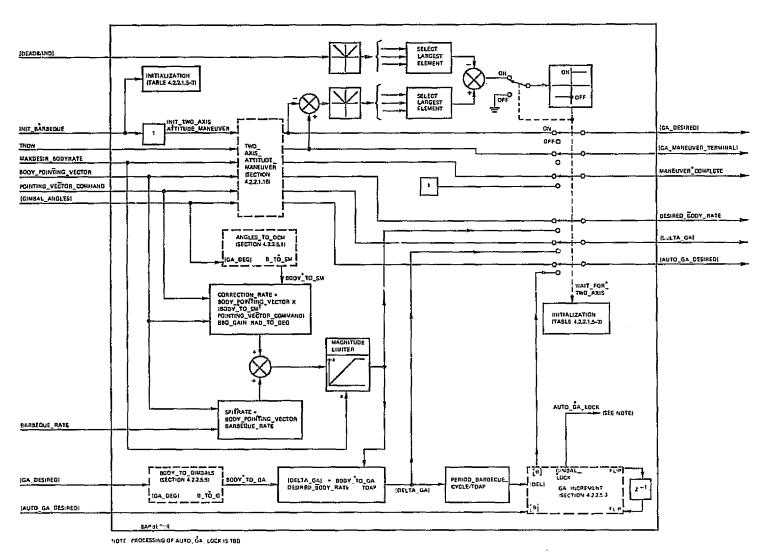


Figure 4.2.2.1.5-1. BARBEQUE.

and the second s

NAME	DESCRIFIION	SOURCE OR DESTINATION	TYPE	I I FANGE	UNIT	SAMELE   FATE (HZ)
Inputs		i	<u> </u>	!		!
	Unit vector, in body axes, to be aligned with POINTING_VECTOR_CHD	GUID or D&C	Z (E) V	-1 to +1	none	15/6
GIMBAL_ANGLES	IMU gimbal angles	SOP	[ A (3) 5	-180 < x  <= 180	deg	15/6
FOINTING_VECTOR_CHD	Unit vector specifying commanded pcinting direction in stable member axes	GUID or D&C	V (3) S 	[-1 to +1	none 	5/6   
BARBEQUE_RATE	Desired barbeque-mode angular   rate	DEC	is i	i TBD	deg/s	[1/maneuver
GA_DESIRED	Desired IBU gimbal angles	BCS_EBBORS	[A (3) S	[-180 < x  <= 180	deq	5/6 
AUTO_GA_DESTRED	Desired IMU gimbal angles	EARBEQUE	[A(3)S	[-180 < x [<= 180	deg	15/6
BAXDESIR_BODYRATE	Desired maximum body angular rate	D&C	İS	10 to 5	deg/s	5/6
TNOW	Current time	SOP	İS	TED	S	15/6
DEADBAND	Attitude deadband	PANEL_SWITCH_INTERP	( A ( 3) S	TBD	deg	5/6
INIT_BARBEQUE	Hodule initialization flag	OFC_RECON	B	j0,1	none	15/6
Outputs		<u> </u>	!	!		
	Desired IMU gimbal angle increments	RCS_ERRORS	A (3) 5	ITPD	l deg	15/6
DESIREC_BODY_RATE	Desired body angular rate	RCS_ERRORS	IV (3) S	!TBD	deg/s	5/6
GA_DESIBED	Desired INV gimbal angles	DEC, RCS_ERRORS	I A (3) S	-180 < x  <= 180	deq 	15/8 I
AUTO_GA_DESTRED	Desired INO gimbal angles	DSC, BARBEQUE	A (3) S	-180 < x  <= 180	l deg	15/6
	Desired terminal IMU gimbal angles	DEC	] A (3) S	-183 < x  <= 183	deg 	1/maneuver
	Flag signifying completion of initial maneuver	DEC	1B 1	10,1	lnone I	15/6

TABLE 4.2.2.1.5-2 BARBEQUE CONSTANTS

I HAME	DESCRIPTION	TYPE	T AVFOE	UNIT     UNIT
ITDAP	Period of BCS DAP cycle	įs	10.04	[s
! LEBIOD BYBBEONE CACTE	Period of BARBEQUE cycle	İs	1.2	. <u>                                     </u>
[RAD_TO_DEG	Radians to degrees conversion factor	is	[180/pi	none

TABLE 4.2.2.1.5-3 BARBEQUE INITIALIZATION REQUIRTHENTS

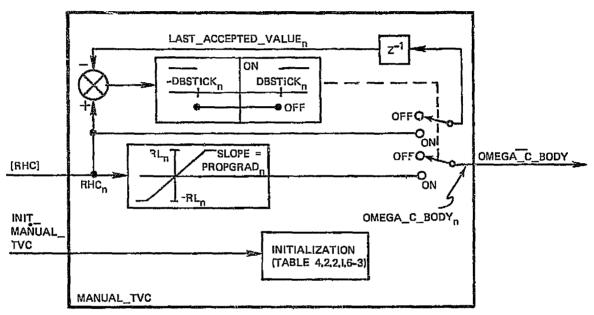
INITIALIZE OF TRANSITION FROM	I INITIALIZE ON TRANSITION TO	I VARIABLE I	INITIAL VALUE (
INIT_BARBEQUE = OFF	1	WAIT_FOR_TWO_AXIS    FLIP	ION I
WAIT_FOR_TWO_AXIS = ON	i		GA_MANEUVEZ_TEPHINAL GA_MANEUVEE_TEFMINAL

## 4.2.2.1.6 MANUAL\_TVC

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A. Function: This module provides inputs to the TVC DAP to generate a three-axis vehicle angular rate corresponding in sense and, up to a limit and subject to the deadband described below, proportional in magnitude to the RHC deflection, during a TVC burn. A movable deadband is incorporated to suppress manual jitter.

- B. Block Diagram: Figure 4.2.2.1.6-1
- C. Processing Rate: 25 Hz
- D. Interface Requirements: Table 4.2.2.1.6-1
- E. Constants: Table 4.2.2.1.6-2
- F. Initialization Requirements: Table 4.2.2.1.6-3



NOTES: 1. ARRAY OR VECTOR SUBSCRIPT IN SHOULD BE TAKEN AS INDICATING THAT THE PROCESSING SHOWN IS FOR ONE ELEMENT, AND ALL THREE ELEMENTS ARE PROCESSED.

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2. THE EFFECT OF THE PROCESSING SHOWN IS TO PLACE A DEADBAND ABOUT RHC  $_{\rm n}$  CENTERED ON THE VALUE OF RHC  $_{\rm n}$  LAST RESPONDED TO.

Figure 4.2.2.1.6-1. MANUAL\_TVC.

TABLE 4.2.2.1.6-1 MANUAL\_TVC INTERFACE REQUIREMENTS

t NAME	DESCRIPTION	SOURCE OR STINATION	†   TYPE 	I I FANGE	opir	SAMELE   RATE (HZ)
Inputs	!		<u> </u>	<u> </u>	 !	!
IRHC	Rotational hand controller   deflection	SOP	A (3) S	TED	deg	125
[INIT_H2HUAL_TVC	Module initialization flag	CFC_RECON	I B	10,1	none	125
loutput	1		<u> </u>	<u> </u>		<u> </u>
CMEGA_C_BODY	1	ROLL component:  RCS_ASSIST_ROLL,  TVC_LAW_ROLL    Pitch and yaw  components:  RCS_ASSIST_PITCH_YAW,  TVC_LAW_PITCH_YAW	( v (3) s   	I ETFD I I I I I	   deq/s               	

# TABLE 4.2.2.1.6-2 MANUAL\_TVC CONSTANTS

i na he	DESCRIPTION	TYPE	VALUE	UNTT
PROPGRAD	[Gain; commanded body rate divided by RHC   deflection	[A (3) S	] TBD	(deg/s)/deg
IDBSTICK	Deadband; required hand controller deflection   from last accepted value	[A(3) S	i TBD	deg
IRL	Rate command limit	1 A (3) S	TBD	deg/s

### TABLE 4.2.2.1.6-3 MANUAL\_TVC INITIALIZATION REQUIREMENTS

I INITIALIZE ON TRAPSITION FROM	  - INITIALIZE ON TRANSITION   TO	VARIABLE	1
[IBIT_HABUAL_TVC = OFF	INIT_MANUAL_TYC = OH	LAST_ACCEPTED_VALUE	10 1

## 4.2.2.1.7 MISC\_TRACKING

- A. <u>Function</u>: This module provides inputs to the RCS DAP to effect attitude control. The command inputs and the internal functions of the module are TBD.
- B. Block Diagram: TBD
- C. Processing Rate: TBD
- D. <u>Interface Requirements</u>: Table 4.2.2.1.7-1
- E. Constants: TBD
- F. <u>Initialization Requirements</u>: TBD

TABLE 4.2.2.1.7-1 HISC\_TRACKING INTERFACE REQUIREMENTS

NAME	DESCRIFTION	SOURCE OR DESTINATION	TYPE	hange	; ;	SAMPLE (HZ)
Inputs		!	<u> </u>	<u>.</u>	<u></u>	<u> </u>
TBD	TED	S02	TBD	TED	ITBD	TED
GIHBAL_AHGLES	INU gimbal angles	SOP	A (3) S	-180 < x  <= 180	l deg	TBD
AUTO_GA_DESIRED	Desired TMU ginbal angles	HISC_TRACKING	(A(3)5	(-180 < x  <= 180	deg   	TBD
Outputs		!		!	!	
DELTA_GA	Desired IMU gimbal angle increments	HCS ERBORS	A (3) S	TBD	1 deg	(TBD
DESIRED_BODY_RATE	Desired body angular rate	RCS_BRRORS	V(3) S	TPD	deg/s	ITBD
GA DESIRED	Desired IMU gimbal angles	DEC, RCS_ERRORS	(A (3) S	(-180 < x (<= 180	l ged	TBD
AUTO_GA_DESIRED	Desired IBU gimbal angles	DEC, HISC_TRACKING	A (3) S	-180 < x  <= 180	deg   deg	TBP
GA_HAHEUVER_TERHINAL	Desired terminal INU gimbal angles	DSC	(A (3) S	-180 < x  <= 180	l deg	TBD 1

### 4.2.2.1.8 OMS\_PRETHRUST\_MANEUVER

- A. Function: This module provides the RCS DAP with inputs to align the expected OMS thrust direction with a desired direction expressed as a unit vector in IMU stable member coordinates. It also supplies the TVC DAP with the position of the orbiter center of gravity (cg) relative to each OMS engine. Upon initialization, the module calculates the engine-to-cg vectors and the expected thrust vector for a one- or two-engine burn. The expected thrust vector is supplied as the vehicle-fixed pointing vector to TWO AXIS ATTITUDE MANEUVER.
- B. Block Diagram: Figure 4.2.2.1.8-1
- C. Processing Rate: 5/6 Hz
- D. Interface Requirements: Table 4.2.2.1.8-1
- E. Constants: Table 4.2.2.1.8-2
- F. <u>Initialization Requirements</u>: Table 4.2.2.1.8-3

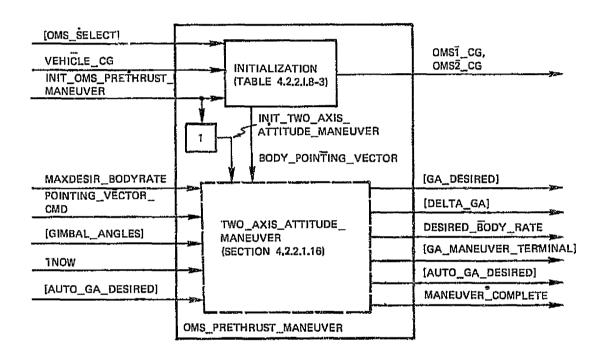


Figure 4.2.2.1.8-1. OMS\_PRETHRUST\_MANEUVER.

TABLE 4.2.2.1.8-1 OMS\_PRETHRUST\_MANEUVER INTERFACE PROVINCEMENTS

NAME	i l DESCRIFTION	SOURCE OR DESTINATION	TYPE	RANGE	l unii L	SAMPLE PATE (HZ)
Inputs				!		· ·
OMS_SELECT	To burn/not to burn status of ONS lengines (1=to burn; 0=not to   burn)	DEC	λ (2) Β	10,1	rione	1/maneuver
	Unit vector specifying commanded   initial ONS thrust direction in   stable member axes	GUID or D&C	V (3) S	-1 to +1	none   	(1/maneuver
	Desired magnitude of body angular rate in automatic attitude maneuvers	DEC	   S 	0 to 5	deg/s   	1/maneuver
THOW	Current time	SOP	s	THD	ls	15/6
YEHICLE_CG	(Vehicle center of gravity, in body axis	SP	∇(3)5	[TED	1   f 	1/maneuver
GIMBAL_ANGLES	INU gimbal angles	SOP	A (3) S	-180 < x  <= 180	deg   l	(1/maneuver
IHIT_OMS_PRETHRUST MANEUVER	Nodule initialization flag	CFC_RECON	B	10,1	I none	15/6
AUTO_GA_DESIRED	Desired INU gimbal angles 	OMS_PRETHRUST_KANEUV-   ER	λ(3)S	1-180 < x 1<= 180	! deg     1	5/6   
Outputs	į			į	 !	<u></u>
DEITA_GA	Desired INU gimbal angle  increments	RCS_ERRORS	( A ( 3) S	TED	! deg !	15/6
DESIREC_BODY_RATE	Desired body angular rate	RCS_ERBORS	V (3) S	TBD	deg/s	1/maneuver
GA_DESIRED	Desired INU gimbal angles	DEC, RCS_ERRORS	A (3) S	]-190 < x  <= 180	l deg 	[5/6
AUTO_GA_DESIRED		CBC, OMS_PRETHRUST_MANEUV- ER	A (3) S	-180 < x  <= 190 	dug   	15/6

TABLE 4.2.2.1.8-1 ONS\_PRETHRUST\_HANEUVER INTERFACE REQUIREMENTS

nade	DESCRIPTION	SOURCE OR DESTINATION	     TYPE 	RANGE	 	[ SAMPLE (HZ)
0851_06	Vactor from OMS1 hinge point to  vehicle cg, in body axes	ENGINE_CG_CND,   ENGINE_PRETHRUST_   TRIH,   DELTA_ONEGA_ONS_ENGI-   HE, TVC_LAW_PITCH_YAW		TBD	[ <del>f</del>	1/maneuver
OHS2_CG	Vector from OBS2 hinge point to   vehicle cg, in body axes 	ENGINE_CG_CHD,   ENGINE_PRETHRUST_TRI-   H,   DELTA_OMEGA_OMS_ENGI-   HE, TVC_LAW_PITCH_YAW	<b>1</b>	TBD	f   l   l	1/maneuver
GA_MANEUVER_TERNINA	LiDesired terminal INU gimbal angles	DEC	Ιλ (3) S	-180 < x  <= 180	deg	1/maneuver
MANEUVER_COMPLETE	Plag signifying completion of maneuver	DSC	] B [	0,1 	none	15/6

TABLE 4.2.2.1.8-2 OHS\_PRETHRUST\_MANEUVER CONSTANTS

NAME	, DESCRIPTION	TYPE	VALUE	i TINU j
	Vector in body coordinate system from origin to ONS engine 1 hinge point	j	(TBD	ift (
ORS2	Vector in body coordinate system from origin to    OBS engine 2 hinge point	A (3) S	TBD	  ft

TABLE 4.2.2.1.8-3 OHS\_PRETHRUST\_HANGUVER INITIALIZATION REQUIREMEN S

INITIALIZE ON TRANSITION FROM	INITIALIZE ON TRANSITION   TO	I VARIABLE I	I INITIAL VALUF (
INIT_ONS_PBETHRUST_HAN EUVER	TRIT_CHS_FEETHRUST_MANEUVER  = ON	OHS1_CG	YEHICLE_CG ~ CM51
 	1	OMS2_CG BODY_POINTING_VECTOR	YEHICLE_CG - GMS2

Note 1: -unit (OMS1\_CG scalar (OMS\_SELECT<sub>1</sub>) + OMS2\_CG scalar (OMS\_SELECT<sub>2</sub>))

# 4.2.2.1.9 PAYLOAD\_ATTITUDE

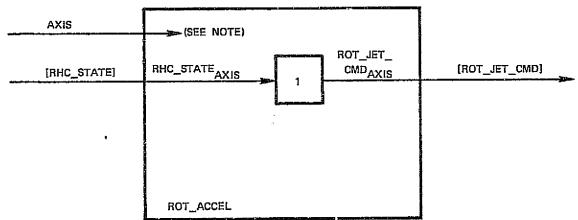
- A. <u>Function</u>: This module provides the RCS DAP with inputs to effect attitude control. The command inputs and the internal functions of the module are TBD.
- B. Block Diagram: TBD
- C. Processing Rate: TBD
- D. <u>Interface Requirements</u>: Table 4.2.2.1.9-1
- E. Constants: TBD
- F. Initialization Requirements: TBD

TABLE 4.2.2.1.9-1 PAYLOAD\_ATTITUDE INTERPACE REQUIREMENTS

na me	DESCRIPTION	SOURCE OR DESTINATION	TYPE	i   FANGE 	   UNIT 	SAMELE ( RATE (HZ)
Inputs		1		·	!	
red	TED	SOP	TBD	TFD	TBD	TBD
SIMBAL_ANGLES	INU gimbal angles	(502	A (3) S	-180 < x  <= 180	l deg	TBD
AUTO_GA_DESIRED	Desired IMU gimbal angles	PAYLOAD_SUPPLIED_CHDS	A (3) S	-180 < x  <= 180	deq	I TBD
Outputs		l i		!	!	<u> </u>
DELTA_GA	Desired IMO gimbal angle increments	BCS_ERRORS	A (3) S	TBD	l geā	TBD
DESIRED_BODY_RATE	Besired body angular rate	RCS_ERRORS	v (3) s	TBD	deg/s	Į TBD
GA_DESINED	Desired IMU gimbal angles	DEC, ECS_ERRORS	A (3) S	-180 < x  <= 180	i deg !	TBD
AUTO_GA_DESIRED	Desired IMU gimbal angles	DEC, -   PAYLOAD_SUPPLIED_CHDS	A (3) S	-180 < x  <= 180	l deg	[TBD
	Desired terminal 180 gimbal angles	₹DEC	A (3) S	-180 < x  <= 180	deq 	[TBD

## 4.2.2.1.10 ROT\_ACCEL

- A. Function: For each vehicle axis that is in the manual acceleration rotation submode, this module provides an input to the RCS DAP to generate a vehicle angular acceleration about that axis while the RHC is out of detent in that axis. The sense of the angular acceleration corresponds to the sense of the RHC deflection. When the RHC is in detent, vehicle rotation about the affected axis is free.
- B. Block Diagram: Figure 4.2.2.1.10-1
- C. Processing Rate: 25 Hz
- D. <u>Interface Requirements</u>: Table 4.2.2.1.10-1
- E. Constants: none
- F. Initialization Requirements: none



NOTE: Array or vector subscript AXIS should be taken as indicating that the processing shown is for that element specified by the present value of AXIS.

Figure 4.2.2.1.10-1. ROT\_ACCEL.

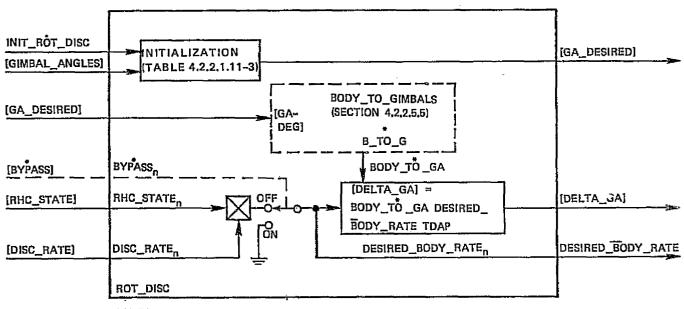
0.2

TABLE 4.2.2.1.10-1 BOT\_ACCEL INTERPACE REQUIREMENTS

i hane	DESCRIPTION	SOURCE OR DESTINATION	i I TYPE	     RANGE 	i i TINU L	SAMPLT RATF (HZ)
Inputs	!	1	Ţ	!	1	1
RHC_STATE	Rotational hand controller command with sense of deflection	RHC_READ	1A (3) I	1-1,3,1	i none	25/axis
AXIS	Body axis for this execution	IOFC_BECOH	†=   I 	11,2,3	Inone	25/axis 
Outputs	!	]		1		
ROT_JET_CHD	Rotation command	JET_SELECT,   PHASE_PLANE	] A (3) I	1-1,0,1	none   l	25/axis

### 4.2.2.1.11 ROT DISC

- A. Function: For each vehicle axis that is in the manual discrete rate rotation submode, this module provides inputs to the RCS DAP to generate a predetermined vehicle angular rate about that axis while the RHC is out of detent in that axis. The sense of the angular rate corresponds to the sense of the RHC deflection. When the RHC is in detent, an attitude hold is performed in the affected axis; the vehicle returns to the attitude it had at the instant the RHC went into detent.
- B. Block Diagram: Figure 4.2.2.1.11-1
- C. Processing Rate: 25 Hz
- D. Interface Requirements: Table 4.2.2.1.11-1
- E. <u>Constants</u>: Table 4.2.2.1.11-2
- F. Initialization Requirements: Table 4.2.2.1.11-3



### NOTE:

ARRAY OR VECTOR SUBSCRIPT is SHOULD BE TAKEN AS INDICATING THAT THE PROCESSING SHOWN IS FOR ONE ELEMENT, AND ALL THREE ELEMENTS ARE PROCESSED.

Figure 4.2.2.1.11-1. ROT\_DISC.

TABLE 4.2.2.1.11-1 ROT\_DISC INTERFACE REQUIREMENTS

HAHE	DESCRIFTION	SOURCE OF DESTINATION	   TYPE 	PANGE	 	SAMELE   PATE (HZ)
Inputs	<u> </u>		<u>-</u>	]		]
BYPASS	Zero output command, by axis   (1=zero output; 0=RHC-commanded   output)	OFC_RECON	] A (3) B	0,1	none	1 1 1
RHC_STATE	Rotational hand controller  Command with sense of deflection	RHC_READ	[A (3) I	-1,3,1 	none	125
GIMBAL_ANGLES	IMU gimbal angles	SOP	λ (3) S	-180 < x  <= 180	deg   deg	125
GA_DESIRED	Desired INU gimbal angles	RCS_ERRORS	[A (3) S	-180 < x  <= 180	  deg 	125 !
DISC_RATE	Desired body angular rate during   deflection of rotational hand   controller	PANEL_SWITCH_INTERP	(A (3) S	TBD	deg/s 	125
INIT_ROT_DISC	Module initialization flag	TOPC_RECON	I B	10,1	none L	25
Outputs	-1 .	!	<u> </u>	į	 [	<u> </u>
DELTA_GA	Desired INU gimbal angle   incresents	RCS_RRRORS	1 A (3) S	TBD !	l   deg 	
DESIRED_BODY_RATE	Desired body angular rate	RCS_ERROBS	I V (3) S	TBD	deg/s	125
GA_DESIRED	Desired IMU gimbal angles	DEC, RCS_ERRORS	λ (3) S	-180 < x  <= 180	L   deg 	125

TABLE 4.2.2.1.11-2 ROT\_DISC CONSTANTS

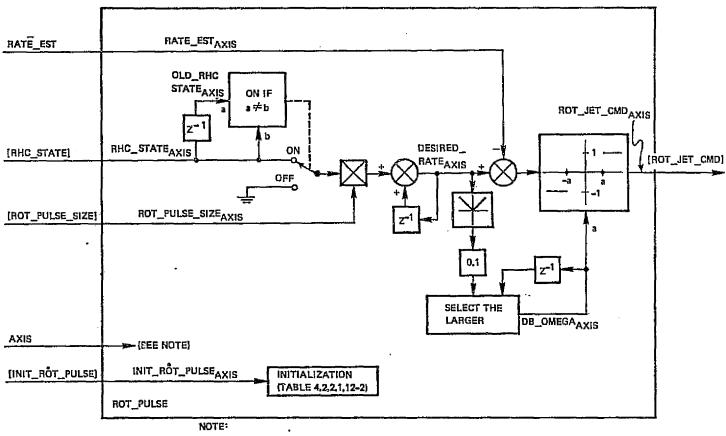
NA HE	DESCRIPTION	TYFF	I VALUE	I THIT	1
	Period of RCS DAP cycle	ĺ	10.64	18	ī

# TABLE 4.2.2.1.11-3 ROT\_DISC INITIALIZATION REQUIFEMENTS

INITIALIZE ON TRANSITION FROM	INITIALIZE ON TRANSITION TO	VARIABLE	INITIAL VALUF     INITIAL VALUF   
INIT_ROT_DISC = OFF	INIT_ROT_DISC = ON	GA_DESTRED	GIMBAL_ANGLES

## 4.2.2.1.12 ROT PULSE

- A. Function: For each vehicle axis that is in the manual pulse rotation submode, this module provides an input to the RCS DAP to generate a predetermined vehicle angular rate increment about that axis for each time the RHC is moved out of detent in that axis. The sense of the angular rate increment corresponds to the sense of the RHC deflection. When the RHC is in detent, the achieved rate is maintained about the affected axis. A rate error deadband is incorporated to prevent severe cycling.
- B. Block Diagram: Figure 4.2.2.1.12-1
- C. Processing Rate: 25 Hz/axis
- D. Interface Requirements: Table 4.2.2.1.12-1
- E. Constants: none
- F. Initialization Requirements: Table 4.2.2.1.12-2



ARRAY OR VECTOR SUBSCRIPT AXIS SHOULD BE TAKEN TO INDICATE THAT THE PROCESSING SHOWN IS FOR THAT ELEMENT SPECIFIED BY THE PRESENT VALUE OF AXIS.

Figure 4.2.2.1.12-1. ROT\_PULSE.

TABLE 4.2.2.1.12-1 ROT\_PULSE INTERFACE REQUIREMENTS

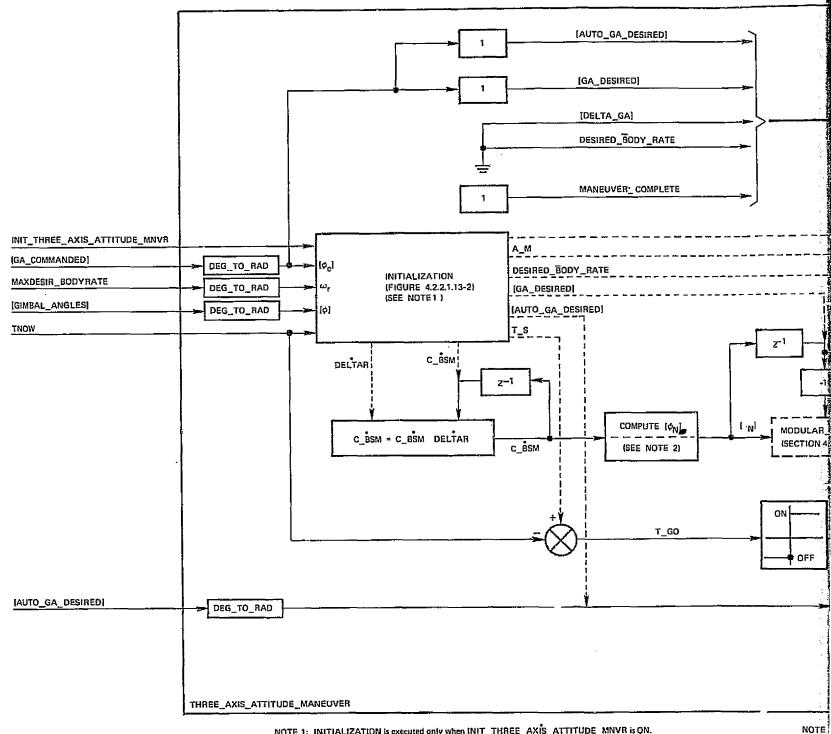
NAME	DESCRIPTION	SOURCE OR DESTINATION	TYPE	PANGE	UNIT	SAMPLE   BATE (HZ)
Inputs			ļ	<u> </u>	]	!
RIC_STATE	Rotational hand controller  comman* with sense of deflection	BHC_READ	[A (3) I	1-1,0,1	inone	25/axis
ATE_EST	Body angular rate estimate	PART1_FILTER	[ V (3) S	TBD	deg/s	25/axis
NIT_ROW_PULSE	Module initialization flag, by	OFC_RECON	] A (3) B	10,1	none	25/axis
ROT_PULSE_SIZE	Desired body angular rate change per deflection of rotational hand controller		A (3) S	TBD	deg/s 	25/axis
XIS	Body axis for this execution	OPC_RECON	1 <u> </u>	11,2,3	Inone	[25/axis
Jutputs			<u> </u>	1	<u> </u>	
OT_JET_CHD	Rotation command	JET_SELECT, PHASE_PLANE	1 A (3) I	1-1,0,1	none	25/axis

## TABLE 4.2.2.1.12-2 ROT\_PULSE INITIALIZATION REQUIREMENTS

INITIALIZE ON TRANSITION   FROM	   INITIALIZE ON TRANSITION   TO	VAPIABLE	INITIAL VALUE	!
INIT_ROT_PULSES (AXIS) = OFF	INIT_ROT_FULSE\$ (AXIS) = ON	i	(FATE_FST\$(AXTS)    -   HC_STATTE (AXIS)	: 

### 4.2.2.1.13 THREE AXIS ATTITUDE MANEUVER

- A. Function: This module provides the RCS DAP with inputs to achieve a desired vehicle attitude, expressed as commanded IMU gimbal angles, through a single equivalent rotation. Calculations to determine the maneuver path, rate and duration are made once, upon initialization. Successive executions during the maneuver interval continue to define the maneuver path by updating the desired IMU gimbal angles and the desired angle increments per RCS DAP cycle. At the end of the maneuver interval, the module effects an attitude hold at the commanded IMU gimbal angles.
- B. Block Diagram: Figure 4.2.2.1.13-1
- C. Processing Rate: 5/6 Hz
- D. Interface Requirements: Table 4.2.2.1.13-1
- E. Constants: Table 4.2.2.1.13-2
- F. Initialization Requirements: Figure 4.2.2.1.13-2

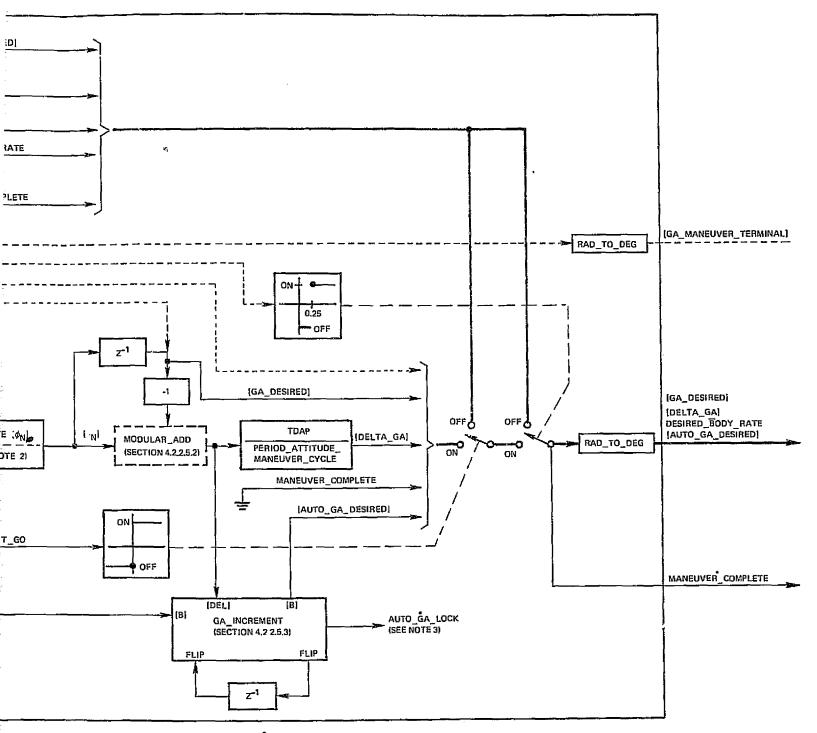


NOTE 1: INITIALIZATION is executed only when INIT\_THREE\_AXIS\_ATTITUDE\_MNVR is ON.

NOTE 2: \$\phi\_{N,3} = \sin^1 (C\_BSM\_2,1)  $\phi_{N,2} = \sin^{-1}(C_BSM_{3,1}/\cos(\phi_{N,3}))$  $\phi_{N,1} = \sin^{-1}(C_BSM_{2,3}/\cos(\phi_{N,3}))$ if C\_BSM<sub>1,1</sub> <  $_{0,0}$ ;  $\phi_{N,2} = \pi \operatorname{sign} (\phi_{N,2}) - \phi_{N,2}$ if C\_B\$M<sub>2,2</sub><<sub>0,0</sub>:  $\phi_{N,1} = \pi \text{ sign } (\phi_{N,1}) - \phi_{N,1}$ 

Figure 4.2.2.1.13-1. THREE AXIS

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NOTE 3: Processing of AUTO\_GA\_LOCK is TBD.

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TABLE 4.2.2.1.13-1 THREE\_AXIS\_ATTITUDE\_NANEUVER INTERFACE REQUIREMENTS

HABE	DESCRIPTION	SOURCE OR DESTINATION	     TYPE 	I I I RANGE	UNIT	SAMPLE   SAMPLE   PATE (HZ)
Inputs		<u> </u>	<u> </u>	1		1
<del>-</del>	Desired magnitude of body angular rate in automatic attitude maneuvers	D&C	!	10 to 5	deg/s I	1/maneuver
GA_COMMANDED	Commanded terminal IMU gimbal  angles	GUID OF DEC	A (3) S	i-100 < x i<= 180	deg	1/maneuver
INIT_THREE_AXIS_ATT- ITUDE_KNYR	Module initialization flag	OFC_RECON	B	0,1	none	15/6
GIMBAL_ANGLES	INU gimbal angles	SOP	λ (3) S	-180 < x  <= 180	deg l	1/maneuver
AUTO_GA_DESTRED	Desired INU gimbal angle	THREE_AXIS_ATTITUDE HABEOVER	I A (3) S	-180 < x  <= 180	deg	15/6
THOW	Current time	SOP	is	TBD Carl		15/6 L
Outputs			<u> </u>	!		<u> </u>
GA_DESIRED	Desired IMU gimbal angles	DEC, RCS_ERRORS	A (3) S	-180 < x  <= 180	deg   deg	15/6 !
DELTA_GA	Desired IMU gimbal angle increments	RCS_ERRORS	A (3) S	IT BD	deg   deg	15/6
DESIRED_EODY_RATE	Desired body angular rate	RCS_EBBORS	∫ v (∃) S	TED	deg/s	11/maneuver
AUTO_GA_DESIRED		D&C, THREE_AXIS_ATTITUDE BANEUYER	A (3) S	1-180 < x 1<= 180	deg   	15/6 1
	Desired terminal IMU gimbal angles	DEC	λ (3) S	1-183 < x 1<= 180	deg	1/maneuver
MANEUVER_COMPLETE	Flag signifying completion of maneuver	1 D&C	! ! B !	0,1   	none I	15/6

104

TABLE 4.2.2.1.13-2 THREE\_AXIS\_ATTITUDE\_MANEUVER CONSTANTS

НА	ME	· DESCRIPTION	TYPE	   VALUE 	t (INIT     UNIT   
[PEBIOD_ATTITUD		Processing period of THREE_AXIS_ATTITUDE_HANEUVER	IS !	11.2	is i
TDAP		Period of FC cycle	is .	1.04	  s
ļī		Identity matrix	A (3) S	1100	i nane
	į			ic 1 c	1 1
1			•	0 0 1	 
RAD_TO_DEG		Radians to degrees conversion factor	ļs	[180/pi.	deg/rad
IDEG_TO_RAD		Degrees to radians conversion factor	is	[pi/180	rad/deg

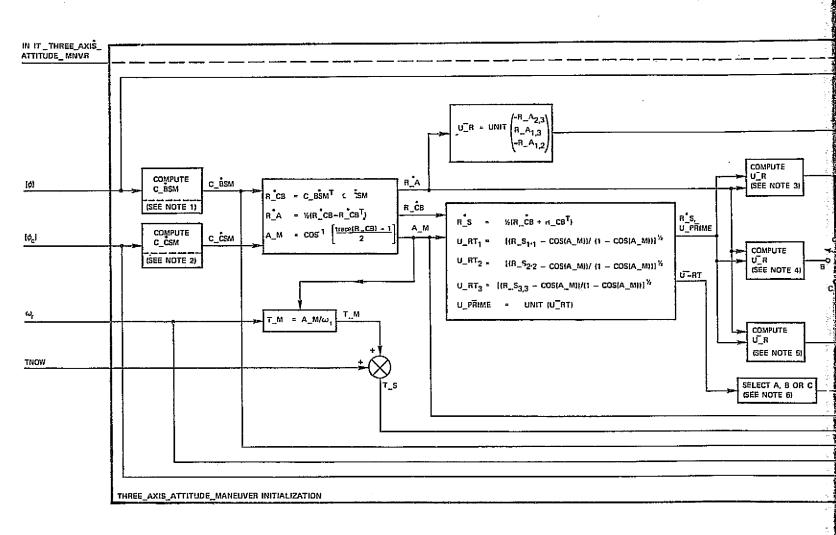
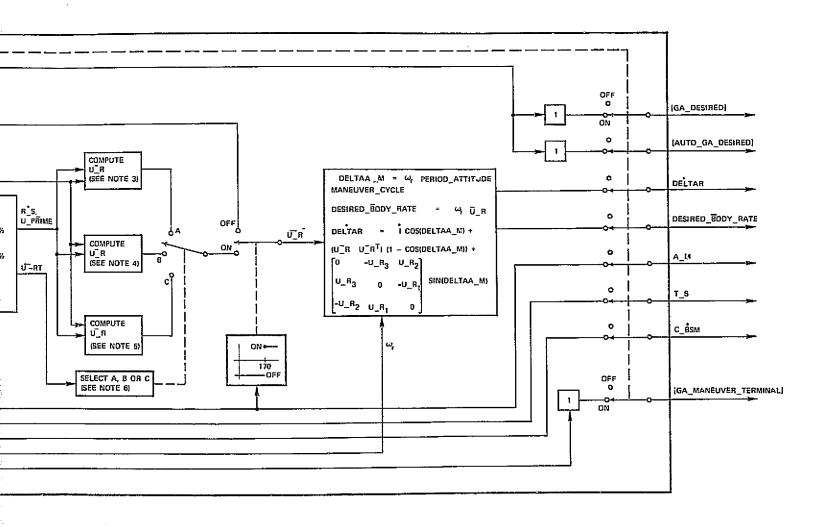


Figure 4.2.2.1.13-2. THREE\_AXIS\_ATTITUDE\_MANEUV (page 1 of 3).



HREE\_AXIS\_ATTITUDE\_MANEUVER initialization page 1 of 3).

NOTE 3

U\_R<sub>1</sub> = U\_PRIME<sub>1</sub> SIGN(-R\_A<sub>2,3</sub>)

U\_R<sub>2</sub> = U\_PRIME<sub>2</sub> SIGN(R\_S<sub>1,2</sub>)

U\_R<sub>3</sub> = U\_PRIME<sub>3</sub> SIGN(R\_S<sub>1,3</sub>)

Figure 4.2.2.1.13-2. THREE AXIS ATTITUDE MANEUVER initialization (page 2 of 3).

## NOTE 4

$$U_R_1 = U_PRIME_1 SIGN(R_A_{1,3})$$

$$U_R_2 = U_PRIME_2 SIGN(R_S_{1,2})$$

$$U_R_3 = U_PRIME_3 SIGN(R_S_{2,3})$$

## NOTE 5

$$U_R_1 = U_PRIME_1 SIGN(-R_A_{1,2})$$

$$U_R_2 = U_PRIME_2 SIGN(R_S_{1,3})$$

$$U_R_3 = U_PRIME_3 SIGN(R_S_{2,3})$$

## NOTE 6

$$A = \{U_RT_1 > U_RT_2\} \cdot \{U_RT_1 > U_RT_3\}$$

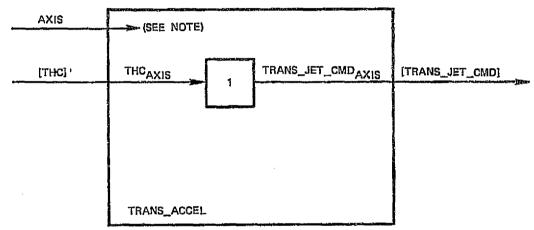
$$\texttt{B} = (\texttt{U\_RT}_2 > \texttt{U\_RT}_1) \cdot (\texttt{U\_RT}_2 > \texttt{U\_RT}_3)$$

$$C = \overline{A + B}$$

Figure 4.2.2.1.13-2. THREE AXIS ATTITUDE MANEUVER initialization (page 3 of 3).

## 4.2.2.1.14 TRANS ACCEL

- A. <u>Function</u>: For each vehicle axis that is in the manual acceleration translation mode, this module provides inputs to the RCS DAP to generate a vehicle translational acceleration along that axis while the THC is out of detent in that axis. The sense of the translational acceleration corresponds to the sense of the THC deflection. When the THC is in detent, vehicle translation along the affected axis is free.
- B. Block Diagram: Figure 4.2.2.1.14-1
- C. Processing Rate: 25 Hz/axis
- D. <u>Interface Requirements</u>: Table 4.2.2.1.14-1
- E. Constants: none
- F. Initialization Requirements: none



NOTE: Array or vector subscript AXIS should be taken to indicate that the processing shown is for that element specified by the present value of AXIS.

Figure 4.2.2.1.14-1. TRANS\_ACCEL.

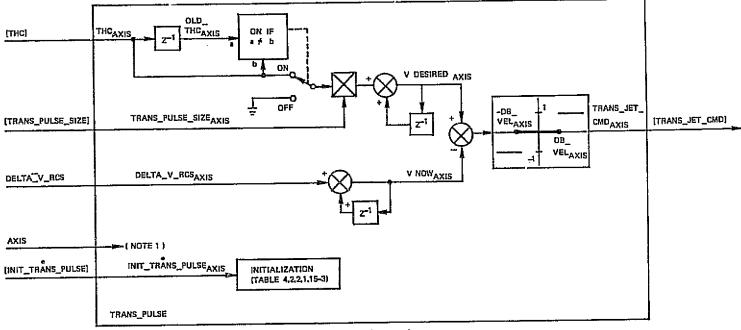
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TABLE 4.2.2.1.14-1 THANS\_ACCEL INTERPACE REQUIREMENTS

HANE	DESCRIPTION	SOURCE OR DESTINATION	TYPE	I I RANGE L	i I I UNIT	SAMPLE RATE (HZ)
Imputs	1	<u> </u>	<u> </u>	!		]
THC	Translational hand controller	SOP	]A (3) I	1-1,0,1	none	125/axis
AXIS	Body axis for this execution	OPC_RECON	ļī 1	11,2,3	none 	25/axis
Outputs	<u> </u>	<u> </u>	]	<u> </u>	<u> </u>	<u> </u>
TRANS_JET_CHD	Translation command	JET_SELECT	[ ] X (3) I	1-1,0,1	none	25/axis

## 4.2.2.1.15 TRANS\_PULSE

- A. Function: For each vehicle axis that is in the manual pulse translation mode, this module provides inputs to the RCS DAP to generate a predetermined vehicle translational velocity increment along that axis for each time the THC is moved out of detent in that axis. The sense of the translational velocity increment corresponds to the sense of the THC deflection. When the THC is in detent, the achieved velocity along the affected axis is maintained. A velocity error deadband is incorporated to prevent severe cycling.
- B. Block Diagram: Figure 4.2.2.1.15-1
- C. Processing Rate: 25 Hz/axis
- D. <u>Interface Requirements</u>: Table 4.2.2.1.15-1
- E. Constants: Table 4.2.2.1.15-2
- F. Initialization Requirements: Table 4.2.2.1.15-3



NOTE: Array or vector subscript AXIS should be taken to indicate that the processing shown is for that element specified by the present value of AXIS.

Figure 4.2.2.1.15-1. TRANS\_PULSE.

## TABLE 4.2.2.1.15-1 TRANS\_PULSE INTERFACE REQUIREMENTS

	·	·				
NAME	DESCRIPTION	SOURCE OR DESTINATION	TYPE	PANGE	 	SAMPLE   BATE (HZ)
Inputs		[	<u> </u>	<u> </u>	<u> </u>	
THC	Translational hand controller  command	SOP	[A (3) I	-1,0,1	[none	25/axis
DELTA_V_RCS	[Modelled vehicle velocity  increment due to ECS jet firings  in the previous cycle	JET_SELECT i	Y (3) S	THD	lf/s	25/axis
INIT_TRANS_PULSE	Module initialization flag, by axis	OFC_RECON	(A (3) B	10,1	none	25/axis
TKARS_PULSE_SIZE	Desired velocity change per ideflection of translational hand controller	PANEL_SWITCH_INTERP	A (3) S	TBD	f/s   	25/axis   
AXIS	Body axis for this execution	OPC_RECON	II L	11,2,3	none 	[25/axis
Outputs		!	<u> </u>	!	ļ	!
TRANS_JET_CHD	Translational command	JET_SELECT	] A (3) I	1-1,0,1	Inone	25/axis

TABLE 4.2.2.1.15-2 TRANS\_PULSE CONSTANTS

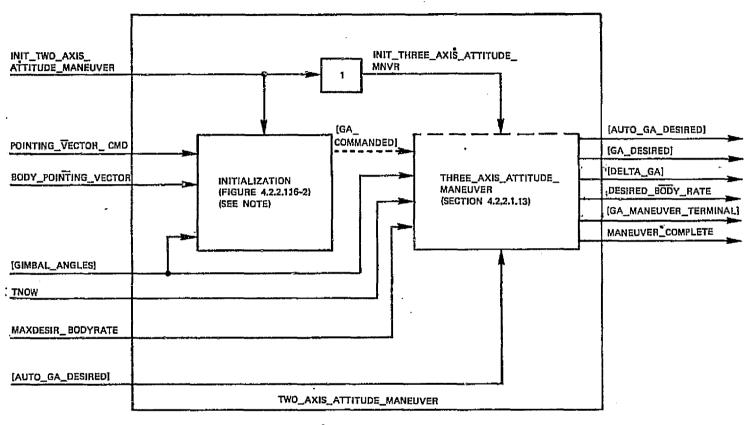
NAME	DESCRIPTION	I TYPE	I VALUE	UNIT !
DB_VEL	Velocity error deadband, by axis	[A (3) S	TBD	f/s

TABLE 4.2.2.1.15-3 TRANS\_PULSE INITIALIZATION REQUIREMENTS

INITIALIZE ON TRANSITION FROM	INITIALIZE ON TRANSITION TO	VARTABLE	I INITIAL VALUE
INIT_TRANS_PULSE\$(AXIS) =  OFF	i	VHOWS (AXIS)  VDESIRED\$ (AXIS)  OLD_THC\$ (AXIS)	0

## 4.2.2.1.16 TWO AXIS\_ATTITUDE\_MANEUVER

- A. <u>Function</u>: This module provides the RCS DAP with inputs to achieve a desired vehicle pointing direction through a single rotation. The desired direction is expressed as a unit vector in IMU stable member coordinates to which a vehicle-fixed vector is to be aligned. No rotation is made about the vehicle-fixed vector. Upon initialization, the module computes the IMU gimbal angles resulting from the vector alignment, and supplies these as commanded IMU gimbal angles to THREE AXIS ATTITUDE MANEUVER.
- B. Block Diagram: Figure 4.2.2.1.16-1
- C. Processing Rate: 5/6 Hz
- D. Interface Requirements: Table 4.2.2.1.16-1
- E. Constants: Table 4.2.2.1.16-2
- F. Initialization Requirements: Figure 4.2.2.1.16-2



NOTE: Initialization is executed only when INIT\_TWO\_AXIS\_ATTITUDE\_MANEUVER is on.

Figure 4.2.2.1.16-1. TWO\_AXIS\_ATTITUDE\_MANEUVER.

TABLE 4.2.2.1.16-1 TWO\_AXIS\_ATTITUDE\_HANEUVER INTERPACE REQUIREMENTS

الماني بين بين بين بين بين المساور و وين المساور و المان	ره و اذات نسمين بر ويو و ويزيان بر ويون برازو و الأناف بي وي وي وي ال					
na ne	DESCRIPTION	SOURCE OR DESTINATION	l   TYPE 	   EANGE	1 1 1	SAMPLE   SAMPLE   FATE (HZ)
Enputs			   	Ī	   	   
BODY_POINTING_VECTOR	Unit Vector, in body axes, to be aligned with POINTING_VECTOR_CMD	GUID OF DSC	V (3) 5	-1 to +1	none	1/maneuver
	Desired magnitude of body angular rate in automatic attitude maneuvers	D&C		10 to 5	deg/s     	1/maneuver
HOR	Current time.	SOP	S	TBD	S   S	5/6
	Unit vector specifying commanded   pointing direction in stable   member axes	GUID or DEC	V (3) S	-1 to +1		1/maneuver
GIMBAL_ANGLES	ILMU gimbal angles	SOP	λ (3) S	-180 < x  <= 180	deg	1/maneuver
NIT_TWO_AXIS_ATTIT- IDE_NANCOVEE	Module initialization flag	OPC_AECON	B   B	10,1	none	5/6
AUTO_GA_DESTRED	Desired IMU gimbal angles	TWO_AXIS_ATTITUDE_HA-   NEUVER	A (3) S	-180 < x  <= 180	deg   deg 	15/6
Outputs	<u> </u>	<u></u>	 !	<u> </u>	<u> </u>	
GA_HAHEUVEB_TEBHINAL	Desired terminal IMU gimbal  angles	DEC	A (3) S	-180 < x  <= 180	deg 	1/maneuver
JA_DESIRED	Desired IMU gimbal angles	DEC, RCS_ERRORS	A (3) 5	-180 < x  <= 180	deg	15/6
AUTO_GA_DESIRED	Desired IMU gimbal angles	D6C,  TWO_AXIS_ATTITUDE_HA-   NEUVER	A (3) S	-180 < x  <= 180	deg     	5/6   
DELTA_GA	Desired INU gimbal angle  increments	RCS_ERRORS	A (3) S	TBD	i deg	15/6
DESIRED_BODY_RATE	Desired body angular rate	RCS_ERRORS	V (3) S	THD	deg/s	1/maneuver
ANEUVER_COMPLETE	Flag signifying completion of  Raneuver	DEC	<u>                                      </u>	15,1	none	15/6
	<del></del>	<del></del>	L		1	

TABLE 4.2.2.1.16-2 TWO\_AXIS\_ATTITUDE\_MANEUVER CONSTANTS

Nane	DESCRIPTION	TYPE	VALUE	TINU
BODY_TO_NB	Yehicle to IMU navigation base transformation	(A (3, 3) S	See Note 1	none
U_SYN	Unit vector in y direction in stable member coordinates	(V (3) S	(0,1,0)	none
O_XL	Unit vector in x direction in mavigation base coordinates	[ V (3) S	(1,0,0)	Inone
PI	Pi.	15	pi	none
RAD_TO_DEG	Radians to degrees conversion factor	- s	180/pi	deq/rad
DEG_TO_RAD	Degrees to radians conversion factor	- <del> s</del>	pi/180	rad/deg

Note 1: 
$$\cos(11^{\circ}) = 0$$
  $\sin(11^{\circ})$   
EODY\_TO\_NB =  $0$  1 0  $\cos(11^{\circ})$   $-\sin(11^{\circ}) = 0$   $\cos(11^{\circ})$ 

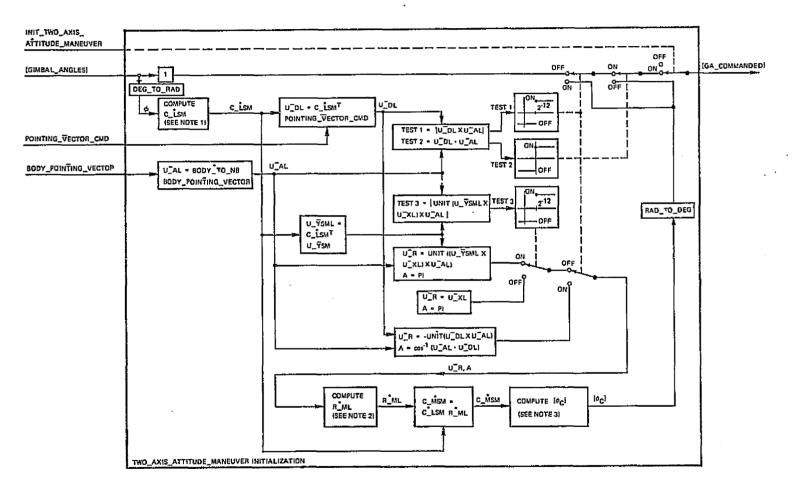


Figure 4.2.2.1.16-2. TWO\_AXIS\_ATTITUDE\_MANEUVER initialization (page 1 of 2).

NOTE 2

$$R_{ML}^{*} = \overset{*}{I} \cos A + (U_{R} \ U_{R}^{T})(1 - \cos A) + \begin{bmatrix} 0 & -U_{R_{3}} & U_{R_{2}} \\ U_{R_{3}} & 0 & -U_{R_{1}} \\ -U_{R_{2}} & U_{R_{1}} & 0 \end{bmatrix} \sin A$$

# NOTE 3

Ħ

$$\begin{split} \phi_{\text{C,3}} &= \sin^{-1} \left( \text{C}_{-} \text{MSM}_{2,1} \right) \\ \phi_{\text{C,2}} &= \sin^{-1} \left( \text{C}_{-} \text{MSM}_{3,1} / \cos \left( \phi_{\text{C,3}} \right) \right) \\ \phi_{\text{C,1}} &= \sin^{-1} \left( -\text{C}_{-} \text{MSM}_{2,3} / \cos \left( \phi_{\text{C,3}} \right) \right) \\ \text{if C}_{-} \text{MSM}_{1,1} &< 0.0; \ \phi_{\text{C,2}} &= \pi \sin \left( \phi_{\text{C,3}} \right) - \phi_{\text{C,2}} \\ \text{if C}_{-} \text{MSM}_{2,2} &< 0.0; \ \phi_{\text{C,1}} &= \pi \sin \left( \phi_{\text{C,1}} \right) - \phi_{\text{C,1}} \end{split}$$

Figure 4.2.2.1.16-2. TWO\_AXIS\_ATTITUDE\_MANEUVER initialization (page 2 of 2).

#### 4.2.2.2 RCS DAP

### 4.2.2.2.1 JET\_SELECT

- A. <u>Function</u>: This module generates jet firing commands required to implement commanded translations and rotations. It also predicts the resulting velocity and angular rate increments. The module contains separate logic for external selection of either the nominal (main) or vernier jets, and takes into account any jet failures. The nominal-jet logic enables external selection of high or low acceleration levels in translation and rotation (except roll) independently, includes algorithms that fire jets to compensate for off-axis and translation/rotation coupling, and allows external selection of forward or aft jets to effect low-level rotations in pitch and yaw independently. This last option is to permit forward/aft RCS fuel use balancing.
- B. Block Diagram: TBD
- C. Processing Rate: 25 Hz
- D. Interface Requirements: Table 4.2.2.2.1-1
- E. Constants: TBD
- F. Initialization Requirements: TBD

NAME	DESCRIPTION	SOURCE OR DESTINATION	TYPE	! ! RANGE	UNIT	SAMPLE (HZ)
Inputs	<u> </u>	]	[	!	Ţ	]
ROT_JET_CMD	Rotation command	PHASE PLANE, ROT_ACCEL, ROT_PULSE OF OPC_RECON	IA (3) I	1-1,0,1 !	none	25   
TRANS_JET_CND	Translation command	AUTO_ECS_TRANS,   TRANS_ACCEL,   TRANS_PULSE or   OFC_RECON	[A (3) I	1-1,0,1	none	25   1   1
JFAIL	RCS jet failure	(RH	(A (44) B	10,1	none	125
NOM_VERHIER_SW	RCS nominal/wernier jet select	PANEL_SWITCH_INTERP	Î B	10,1	none	125
ROT_HI_LO_SW	Rotation acceleration level  select	PANEL_SWITCH_INTERP	A (3) B	10,1	none	125
JFAIL_CHANGE	Plag signifying change in JFAIL	IRM	IB	10,1	none	125
	Translation acceleration level select	RM, PANEL_SWITCH_INTERP	1 A (3) B	10,7	Inone	[ 25
LO_PITCH_TAIL_NOSE	Tail or nose jet select for low- level pitch rotation	I Dec	1 B	10,1	none	125 I
	Tail or nose jet select for low- level yaw rotation	DEC	1 B	10,1	Inone	125 !
OFF_AXIS_COMP_THRES- HOLD	Threshold for off-axis compensation firings	PAHEL_SWITCH_INTERP	IA (6) S	TBD	f/s,deg/s 	[25 ]
INIT_JET_SELECT	Hodule initialization flag	[OFC_RECON	ŢB	10,1	none	125
vzhicle_inversb_ine- atia	Inverse of vehicle inertia	SF   L	H(3,3) S	TBD	1/((slug)(f) -   (f))	25
Outputs	ı	1	 T	 T	1	ļ
JONIST	kCS jet on command	ISOP, RH	IA (44) B	10,1	Inone	   25
DELTA_OHEGA_RCS	Modelled body angular rate   increment due to RCS jet firings	PART2_FILTEP	(3) S	TBD	deg/s	1 1 1
	  Kodelled vehicle velocity  increment due to RCS jet firings	TRANS_PULSE	[ V (3) S	TBD	f/s 	25

### 4.2.2.2.2 PHASE PLANE

- A. <u>Function</u>: For each body axis requiring RCS rotation control and not in the manual rotation acceleration or manual rotation pulse submode, this module determines whether an angular rate change is needed and the sign of the desired rate change. The vehicle is driven into and held in a limit cycle about the desired attitude and attitude rate. The parameters of the limit cycle are selected to minimize a weighted combination of response time and RCS fuel use. The attitude deadband is selected externally, and the module takes into account the undesired vehicle angular acceleration—the sum of the disturbance and modelled undesired accelerations.
- B. <u>Block Diagram</u>: Figures 4.2.2.2-1 through 4.2.2.2.2-8; Tables 4.2.2.2-1 and 4.2.2.2.2-2.
- C. Processing Rate: 25 Hz
- D. Interface Requirements: Table 4.2.2.2.2-3
- E. Constants: Table 4.2.2.2.2-4
- F. Initialization Requirements: Table 4.2.2.2.2-5

Note: PHASE PLANE is in the process of redesign as of the publication date of this document.

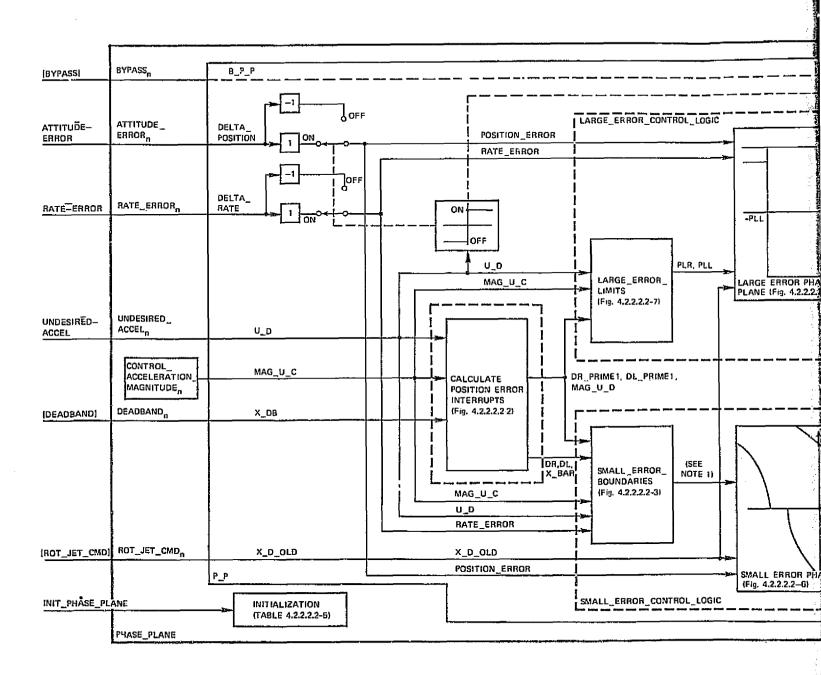
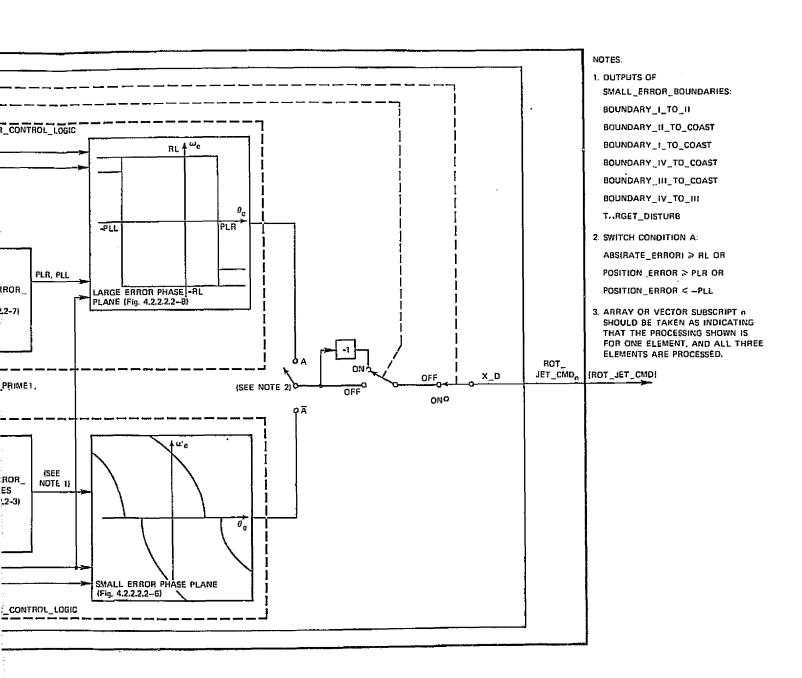


Figure 4.2.2.2-1. PHASE\_PLANE

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2.2.2-1. PHASE PLANE

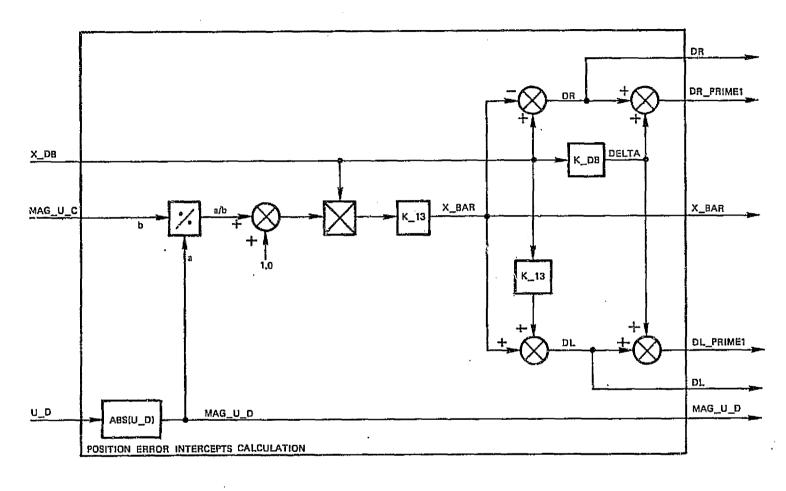


Figure 4.2.2.2.2-2. Position error intercepts calculation.

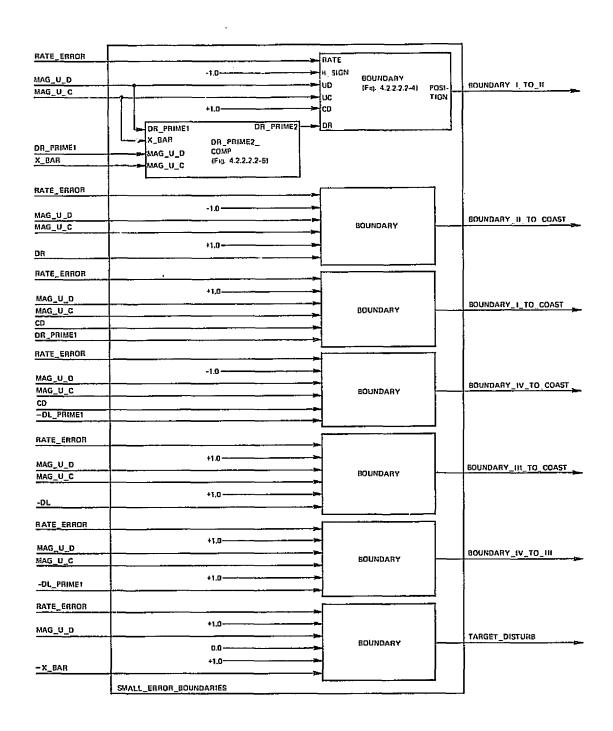


Figure 4.2.2.2.3. SMALL\_ERROR\_BOUNDARIES.

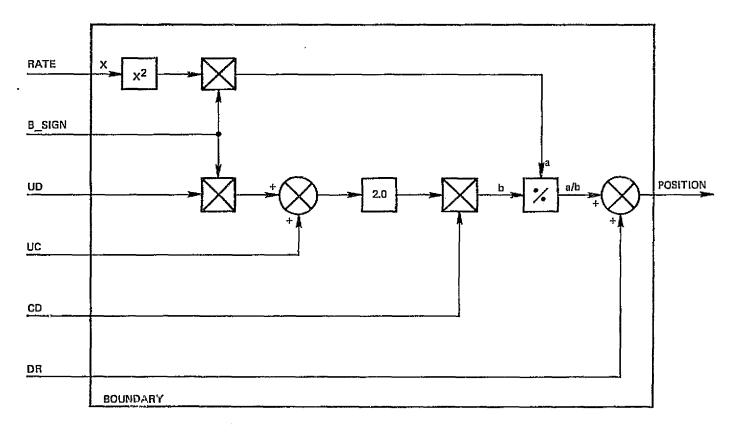


Figure 4.2.2.2-4. BOUNDARY.

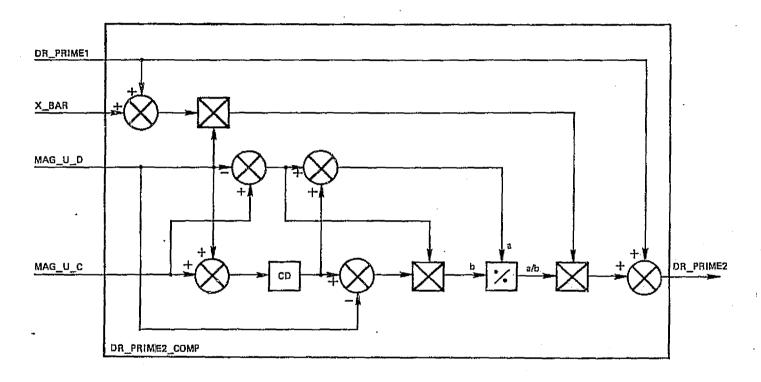


Figure 4.2.2.2.2-5. DR\_PRIME\_2\_COMP.

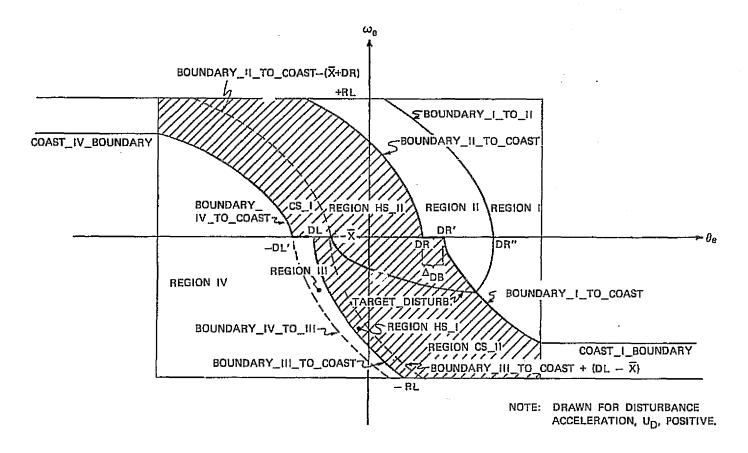


Figure 4.2.2.2.2-6. Small error phase plane.

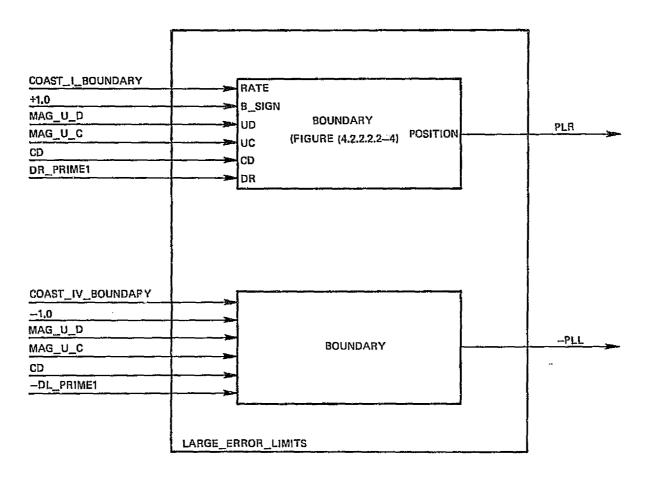


Figure 4.2.2.2.2-7. LARCE\_ERROR\_LIMITS.

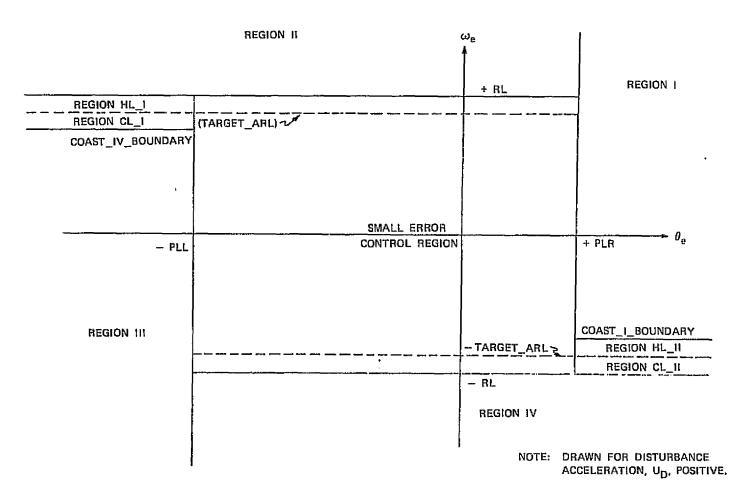


Figure 4.2.2.2-8. Large error phase plane.

Table 4.2.2.2.1. Control actions in small error control regions.

REGION	CONTROL ACTION, X_D VALUE
I	Drive state to BOUNDARY_1_TO_COAST, -1
II	Drive state to TARGET_DISTURB, -1
III	Drive state to zero rate, +1
IV	Drive state to BOUNDARY_IV_TO_COAST, +1
HS_I	<pre>If X_D_OLD = +1 (i.e., if coming from LARGE_ERROR_ CONTROL_LOGIC or REGION_III) then Command +1 until zero rate is achieved, else Command 0.</pre>
HS_II	If X_D_OLD = -1 (i.e., if coming from LARGE_ERROR_ CONTROL_LOGIC or REGION_II) then Command -1 until TARGET_DISTURB is reached, else Command 0.
cs_i	Coast, 0
cs_II	Coast, 0

Table 4.2.2.2.2. Control actions in large error control regions.

REGION	CONTROL ACTION, X_D VALUE
I	Drive state to -(TARGET_ARL), -1
II	Drive state to TARGET_ARL, -1
III	Drive state to COAST_IV_BOUNDARY, +1
IV	Drive state to -RL, +1
HT <sup>-</sup> I	<pre>If X_D_OLD = -1 (i.e., if coming from Region II) then Command -1 until TARGET_ARL is reached, else Command 0.</pre>
HIII	<pre>IF X_D_OLD = -1 (i.e., if coming from Region I) then Command -1 until -(TARGET_ARL) is reached, else Command 0.</pre>
Cr_I	Coast, 0
CL_II	Coast, 0

TABLE 4.2.2.2.3 PHASE\_PLANE INTERPACE REQUIREMENTS

NAME	DESCRIPTION	SOURCE OR DESTINATION	I I TYPE	I I BANGE	UNIT	SAMPLE   RATE (HZ)
Inputs		ļ	<u> </u>	1	 i	
BYPASS	Non-execution command, by axis   (1=do not execute; 0=execute)	CFC_RECON	1 A (3) B	10,1	pone	125
ATTITUDE_ERROR	Body angle error	Roll Component:  BCS_ERRORS or  BCS_ASSIST_ROLL  Pitch and yaw  Components:  RCS_URRORS or  BCS_ASSIST_PITCH_YAW	V (3) S	TBD	deg 	25 
RATE_ERROR	Body angular rate errox	Roll component:   RCS_EERORS or  RCS_ASSIST_ROLL  Pitch and yaw  Components:  RCS_ERRORS or  RCS_ASSIST_PITCH_YAW	V (3) S	TBD	[deg/s   	[25] 
UNDESINED_ACCEL	Total undesired body angular   acceleration	PART 1_FILTER	V (3) S	TBD	deg/((s)(s))	125
DRADBAND	Attitude deadband	PANEL_SWITCH_INTERP	A (3) S	ITBD	deg	125
CHD_TAL_TON	Rotation command from previous	[PHASE_PLANE, [ROT_ACCEL, ROT_PULSE   OF OFC_RECON	I (E) I	1-1,0,1	none	25   I 
INIT_PHASE_PLANE	Module initialization flag	I ORC TECOH	B   L	(0,1 .L	I none	125
Outputs	<u> </u>	!	<u> </u>	!	!	<u> </u>
ROT_JET_CHD	Rotation command	JET_SELECT	IA (3) I	1-1,0,1	Inone	125

TABLE 4.2.2.2.4 PHASE\_PLANE CONSTANTS

na he	DESCRIPTION	TYPE	VALUE	UVI"
CD	SHITCH CURVE DESIGN PARAMETER	IS	0.8	SKON
	Rate error boundary of lower coasting region of large error phase plane	15 	1-3.0	deq/s
	Rate error boundary of upper coasting region of large error phase plane	is I	COAST_I_BOUNDARY	deg/s
K_DB	Praction of deadband to be used for "ledges" (delta\$(DB) in small error phase plane)	s I	[0.2 i	none
к_13	Limit cycle design parameter	S	1.0/3.0	none
	Rate error boundary between large and small error phase planes	S	4.0 	đeg/s
	Target average rate limit inside large and small error phase plane coast region	S	(COAST_I_BOUNDAPY	dea/s
	Magnitude of available control acceleration for each axis	1 A (3) S	TBD	deg/((s) (s)) 

### TABLE 4.2.2.2.2-5 PHASE\_PLANE INITIALIZATION REQUIREMENTS

INITIALIZE ON TRANSITION FRCE	I INITIALIZE ON TRANSITION TO	   VARIABLE 	ENITIAL VALUE
INIT_PHASE_PLANE = OFF	INIT_PHASE_PLANE = ON	ROT_JET_CHD	1 Û

#### 4.2.2.3 RCS ERRORS

- A. Function: This module obtains the vehicle attitude and angular rate errors, based upon commands from the attitude drivers and measurement data from the IMU and the State Estimator. It also performs the incrementation required to interface position commands from the attitude drivers, some of which operate at 5/6 Hz, to the RCS DAP rate of 25 Hz. The desired gimbal angles are updated by the smoothing increment and the result subtracted from the actual gimbal angles. The remainder is the gimbal angle error, which is converted to body coordinates to yield body angle or attitude error. The angular rate error is obtained as the difference between the estimated and desired body rates.
- B. Block Diagram: Figure 4.2.2.3-1
- C. Processing Rate: 25 Hz
- D. Interface Requirements: Table 4.2.2.2.3-1
- E. Constants: none
- F. Initialization Requirements: Table 4.2.2.2.3-2

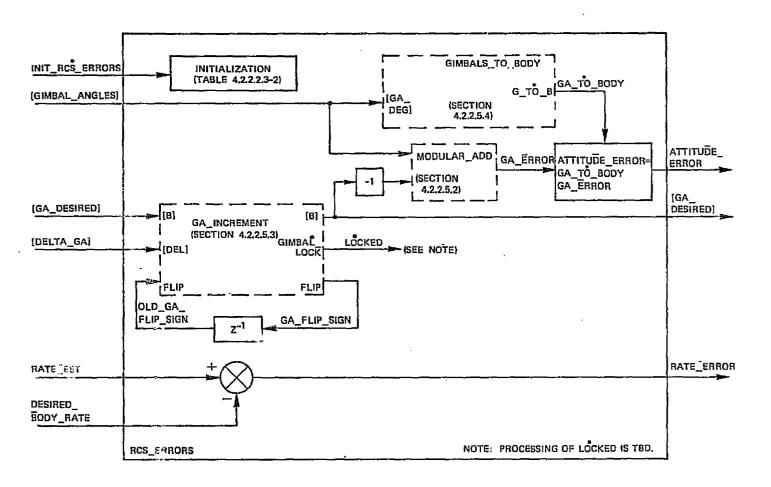


Figure 4.2.2.3-1. RCS\_ERRORS.

## TABLE 4.2.2.3-1 BCS\_ERRORS INTERFACE REQUIREMENTS

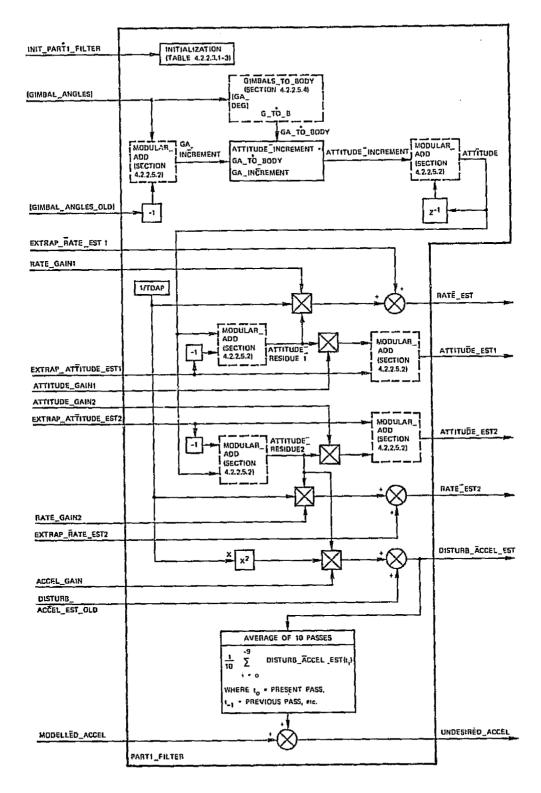
HAME	DESCRIPTION	SOURCE OR DESTINATION	   TYPE 	I I FANGE	-     UNIT 	SAMPLE   BATF (UZ)
Inputs	<u> </u>	Annual telephone mail and the page and telephone and telep	<u></u>   	]	[	1
ga_desired	Desired INU gimbal angles 	ATTITUDE_HOLD, ATTITUDE_LCL_YERTICA- L, BARBEQUE, MISC_TRACKING, OMS_PRETHRUST_MANEUV- LER, PAYLOAD_SUPPLIED_ CHDS, ROT_DISC, THREE_AXIS_ATTITUDE HANEUVER, OF TWO_AXIS_ ATTITUDE_HANEUVER OF RCS_ERRORS	1 . 1 1 1 1	-180 < x  <= 180                     	i deg 	25   1       1   1   1   1   1   1   1
DELTA_GA	Desired IMU gimbal angle   increments   	ATTITUDE_HOLD, ATTITUDE_LCL_VERTICA- L, BARBEQUE, MISC_TRACKING, OMS_PRETHRUST_HANEUV- ER, PAYLOAD_SUPPLIED_ CHDS, ROT_DISC, THREE_AXIS_ATTITUDE MANEUVER, OF THO_AXIS_ATTITUDE_HA- NEUVER	1 1 1 1 1 1	FED	deg	1 25 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
DESIRED_BODY_RATE	Desired body angular rate	ATTITUDE_HOLD,   ATTITUDE_LCL_VBRTICA-   L, BARBEQUE,   HISC_TRACKING,   OMS_PRETHRUST_HANEUY-   ER, PAYLOAD_SUPPLIED_    CMDS, ROT_DISC,   THREE_AXIS_ATTITUDE   MANEUYER, OF   TWO_AXIS_ATTITUDE_HA-   NEUVER	 	TBD	deg/s   l   l   t   l   l	125 
GIMBAL_ANGLES	IIMU gimbal angles	SOP	( λ (3) S	-180 < x  <= 180	! [deg !	1 25

TABLE 4.2.2.3-1 RCS\_ERRORS INTERFACE REQUIREMENTS

Wane	DESCRIPTION	SOURCE OR DESTINATION	 	   FANGE	l unit	I SAMPLE I FATE (HZ)
rate_est	Body angular rate estimate	PART1_FILTER	(¥ (3) S	TBD	deg/s	125
INIT_RCS_EARORS	Bodule initialization flag	OFC_BECON	B	10,1	l none	125   1
Outputs		]	1	Ī	!	
ATTITUDE_ERROR .	Body angle error	PHASE_PLANE	V (3) S	TBD	deg	125
RATE_ELROL	Body angular rate error	DEC, PHASE_PLANE	V (3) S	TBD	deg/s	125
GA_DESIRED	Desired INT gimbal angles	DEC, RCS_ERRORS, ATTITUDE_LCL_VERTICA- L, BARBEQUE, FOT_DISC		-180 < x  <= 180	i deg	25

TABLE 4.2.2.3-2 RCS\_ERRORS INITIALIZATION REQUIREMENTS

; ; ;	INITIALIZE ON TRANSITION FRCH		OH TRANSITION TO	VARIABLE	1 INITIAL VALUF	     
-	INIT_RCS_ERRORS = OFF	[INIT_BCS_EBRO	RS = ON	OLD_GA_FLIP_SIGN	( TBD	i l



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Figure 4.2.2.3-1. PARTI\_FILTER.

TABLE 4. 2. 2. 3. 1-1 PART1\_FILTER INTERPACE REQUIREMENTS

I WARE	DESCRIPTION	SOURCE OF DESTINATION	I I I TYPE	I I RANGE I	I I I DNIT	SAMPLE   BATF (HZ)
!Inputs		1	<u> </u>	1		1
GIMBAL_AMGLES	INU gimbal angles	SOP	[A (3) S	-180 < x  <= 180	deg	125
	INU gimbal angles from previous cycle	PART2_FILTER	1 A (3) S	-180 < x  <= 180	deg 	125
EXTRAP_ATTITUDE_EST1	Extrapolated filter 1 body angle estimate from previous cycle	PART2_FILTER	(∀(3)5	-180 < x  <= 180	deg   	! 25 
i	Extrapolated filter 1 body angular rate estimate from previous cvrle.	PART2_FILTER	V (3) S   	TBD   	deg/s     .	[25]
Ird	Body angular disturbance acceleration estimate from previous cycle	PART2_FILTER	(V (3) S	TBD	deg/((s) (s))   	[25]
HODELLED_ACCEL	Modelled undesired body angular acceleration from previous cycle	PART2_FILTER	V (3) S	TBD	deg/((s)(s)) 	125
ATTITUDE_GAIN1	Filter 1 gain for attitude term	OFC_RECON	İS	TBD	none	125
ATTITUDE_GAIN2	Filter 2 gain for attitude term	OFC_RECON	İS	TBD	none	125
PATE_GAIN1	Filter 1 gain for rate term	OFC_RECON	İs	TBU	none	125
RATE_GAIR2	Filter 2 gain for rate term	OFC_RECON	İs	TBD	none	125
ACCEL_GAIN	Filter 2 gain for acceleration term	OFC_RECON	(S	TBD	none	125
INIT_PARTI_FILTER	Module initialization flag	OFC_RECON	IB	10,1	none	125
EXTRAP_ATTITUDE_EST2	Extrapolated filter 2 body angle estimate from previous cycle	PART2_FILTER	(V (3) 5	-180 < x  <= 180	deg 	125 !
	Extrapolated filter 2 body angular rate estimate from previous cycle	PART2_FILTER 	V (3) S   	TBD	deg/s   	125 ( 1

TABLE 4.2.2.3.1-1 PARTI\_FILTER INTERFACE & EQUIPMENTS

NAME	DESCRIPTION	SOURCE OR   DESTINATION	 	   FANGE	T	I SAMELY I BAIF (FZ)
Outputs		į		!	!	<u></u>
ATTITUDE_EST1	Filter 1 body angle estimate	PART2-FILTER	v (3) s	-180 < x  <= 180	i ged I	1 (25 !
RATE_EST .	Filter 1 body angular rate  estimate 	B&C, PART2 FILTER,   RCS_ERRORS, ROT_PULSE   Roll component:   RCS_ASSIST_ROLL   Pitch and yaw   Components:   RCS_ASSIST_PITCH_YAW,   PITCH_YAW_ASSIST_COM-	 	ITBD I	dea/s   	125 
UNDESTRED_ACCEL	Total undesired body angular  acceleration	PHASE_PLANE,	V (3) S	TBD	dej/((s) (s))	125
DISTURB_ACCEL_EST	Body angular disturbance  acceleration'estimate	PART2_FILTES Roll   component: BH	V (3)S	TBD	[dea/ ({s} (s) }	125
ATTITUDE_EST2	Filter 2 body angle estimates	PART2_FILTEF	V (3) S	-180 < x  <= 180	[deq	125
ATE_EST2	Filter 2 body angular rate  estimate	PART2_FILTEF	V (3) S	TED	dea/s	125

TABLE 4.2.3.1-2 PART1\_FILTER CONSTANTS

NA MB	I I	DESCRIPTION	I TYI	E I	VALUE	i   	TINU	1
[TDAP	[Period o	of state estimator cycle	ĮS	10.0		s		

TABLE 4.2.2.3.1-3 PART1\_FILTER INITIALIZATION REQUIREMENTS

INITIALIZE ON TRANSITION FROM	I INITIALIZE ON TRANSITION TO	VARIABLE	INITIAL VALUE     INITIAL VALUE   
ITHIT_PART1_FILTER = OFF		ATTITUDE EXTRAP_ATTITUDE_EST1 EXTRAP_ATTITUDE_EST2 EXTRAP_RATE_EST1 EXTRAP_RATE_EST2	GIMBAL_ANGLES
! !		DISTURB_ACCEL_EST_OLD  DISTURB_ACCEL_EST for previous 9 passes  (stored in "average of 10 passes" function)	C

#### 4.2.2.3.2 PART2 FILTER

- A. Function: This module extrapolates the vehicle state for the next FC cycle as a function of the estimated present state and the expected angular rate changes due to control effector use; it also models angular acceleration. It first computes the extrapolated angular rate increment as the sum of the control-effector and undesired-acceleration rate increments. This rate increment is then filtered with attitude and angular rate estimates in two parallel filters (a "rate" filter and an "acceleration" filter) to obtain attitude and angular rate extrapolations. Angular acceleration modelling is TBD.
- B. Block Diagram: Figure 4.2.2.3.2-1
- C. Processing Rate: 25 Hz
- D. Interface Requirements: Table 4.2.2.3.2-1
- E. Constants: Table 4.2.2.3.2-2
- F. Initialization Requirements: none

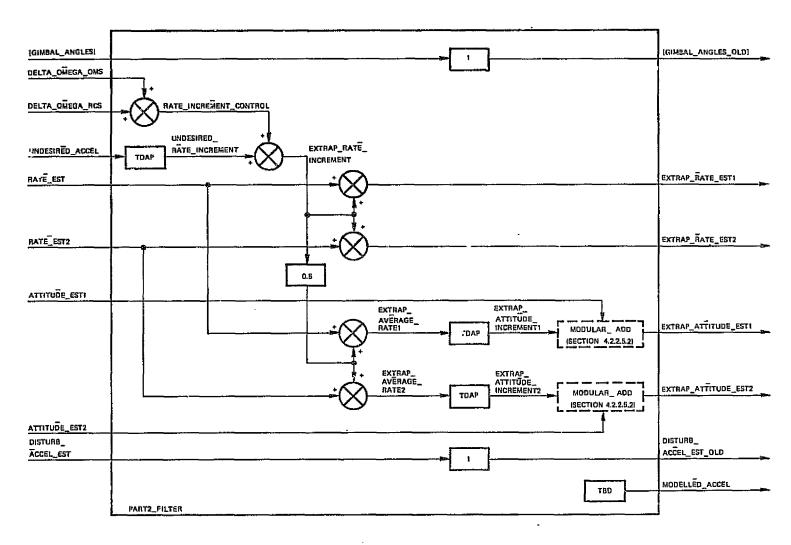


Figure 4.2.2.3.2-1. PART2\_FILTER.

TABLE 4.2.2.3.2-1 PART2\_FILTER INTERPACE PEQUIREMENTS

NA KE	DESCRIPTION	SOURCE OR DESTINATION	1     TYES 	I IANGE	 	SAMPLE   SATT (HZ)
Inputs				1		 ]
ATTITUDE_BST 1	Filter 1 body angle estimate	PART1_FILIEL	V (3) S	[-18] < x  <= 180	deg 	125
BATE_EST	Filter 1 body angular rate lestimate	PART1_FILTER	(V (3) S	TBD	ged∖a 	125
ATTITUDE_EST2	Pilter 2 body angle estimate	PART1_FILTER	V (3) 5	-185 < x  <= 180	deg	125
BATE_EST2	Filter 2 body angular rate estimate	PART1_FILTE	V (3) S	irer I	deq/s	125
UNDESTRED_ACCEL	Total undesired body angular acceleration	PART1_FILTER	į V (3) 5	[TBD	deq/((s)(s))	125
DISTURB_ACCEL_EST	Body angular disturbance  acceleration estimate	PART1_FILTER	V (3)5	TBD	deg/((s)(s))	125
DELTA_OMEGA_OMS	Modelled body angular rate  increment due to OMS TVC	DELTA_OMEGA_OMS_ENGI-  NE or PART2_FILTER	V (3) S	TBD	dea/s	125 1
DELTA_ONEGA_RCS	Modelled hody angular rate  increment due to RCS jet firings		V (3) S	TBD 	ded/s	125
GIMBAL_ANGLES	IMU gimbal angles	SOP 	(A(3)5	-18. < x  <= 180	deg   	125
Outputs		 		!		   
EXTRAP_ATTITUDE_EST1	Extrapolated filter 1 body angle estimate	PART1_FILTES	V (3) S	-181 < x  <= 181	i dea	[25]
	(Extrapolated filter 1 body  angular rate estimate	PART1_FILTEF	V (3) S	TPD	deq/s	125 l
DISTURB_ACCEL_EST_O- LD	Body angular disturbance   acceleration estimate	PARTI_PILTER	V (3) 3	T Pr:	de 7/ ((a) (s) )	125
	L	4	L	A		*

TABLE 4.2.2.3.2-1 PART2\_FILTER INTERFACE REQUIREMENTS

HABE	DBSCRIFTION	SOURCE OR DESTINATION	   TYPE	   FANGE	 	SAMPLE HATE (HZ)
	Hodelled undesired body angular acceleration	PART1_FILTER	V (3) S	(TBD	deg/((s) (s)) 	[25
	Extrapolated filter 2 body angle estimate	PART1_PILTER	V (3) S	-180 < x  <= 180	l deg	125
	Extrapolated filter 2 body angular rate estimate	PART1_FILTER	V (3) S	[TBD	deg/s	125
GIMBAL_ANGLES_OLD	IBU gimbal angles	PART1_FILTER	A (3) 5	-180 < x  <= 180	deg 	125

TABLE 4.2.2.3.2-2 PART2\_FILTER CONSTANTS

NAME	DESCRIPTION	TABE	VA LUE	
12DAP	Period of FC cycle	ıs	0.0u	ıs 1

#### 4.2.2.4 TVC DAP

))

## 4.2.2.4.1 DELTA\_OMEGA\_OMS\_ENGINE

- A. <u>Function</u>: This module computes the modelled body angular rate increment due to torque from the OMS engines during a TVC burn.
- B. Block Diagram: Figure 4.2.2.4.1-1
- C. Processing Rate: 25 Hz
- D. <u>Interface Requirements</u>: Table 4.2.2.4.1-1
- E. Constants: Table 4.2.2.4.1-2
- F. <u>Initial ation Requirements</u>: none

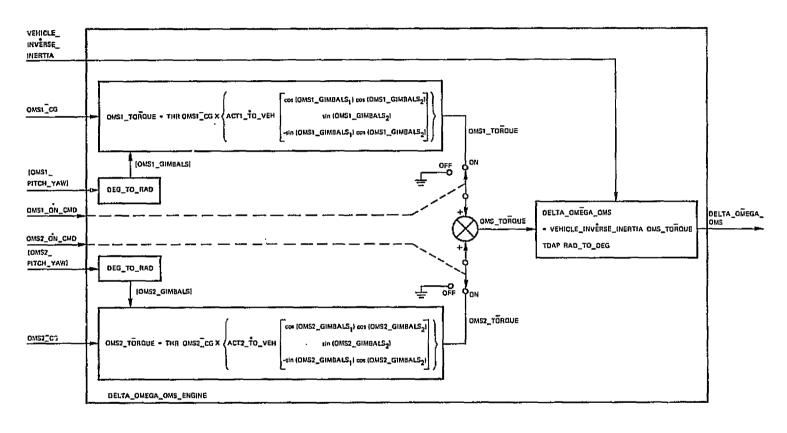


Figure 4.2.2.4.1-1. DELTA\_OMEGA\_OMS\_ENGINE.

TABLE 4.2.2.4.1-1 DELTA\_ONEGA\_OMS\_ENGINE INTEFFACE REQUIREMENTS

NAME	DESCRIPTION	SOURCE OA DESTINATION	TYPE	i   FANGE 	   UNIT 	SAMELF PATE (HZ)
Inputs				 	1	
	Vector from ONS1 hinge point to vehicle cg, in body axes	OMS_PRETHRUST_HANEUV-	V (3) S	TBD	f   f	25
	Vector from ORS2 hinge point to vehicle cg, in body axes	OMS_PRETHPUST_MANEUV-	V (3) 5	TBC	[f	125
ONS1_PITCH_TAW	OMS1 engine pitch and yaw	SOP	A (2) S	TBD	l deg	25
OMS2_PITCH_YAW	OMS2 engine pitch and yaw	SOP	λ (2) S	TBD	Idea	25
OMS1_ON_CMD	ONS1 on conmand	OHS_ENG_CHD	B	10,1	none	25
ONS2_ON_CUD	OHS2 on command	CHS_BNG_CHD	e	15,1	1 none	25
Vehicle_invepse_ihe- rtia	Inverse of vehicle inertia		M (3,3) S	ITBD	[1/((slug)(f)-  (f))	25 
Outputs						
	Modelled body angular rate increment due to CMS TVC	PART2_FILTER	V (3) S	irec 1	deg/s	   25 

TABLE 4.2.2.4.1-2 DELTA\_OMEGA\_ONS\_ENGINE CONSTANTS

HA ME	DESCRIPTION	TYPE	VALUE	TIKU
ACTI_TO_VEH	OMS1 actuator axes to vehicle axes  transformation matrix	(h (3, 3) s	See Note 1	Inone
ACTZ_TO_VEH	OMS2 actuator axes to vehicle axes transformation matrix	H (3, 3) S	See Note 2	Inone
THE	Nominal thrust of a single OBS engine	İs	6000	lbf
TDAP	Autopilot minor cycle time	s	1.04	s
DEG_TO_RAD	Degrees to radians conversion factor	is	[pi/180	rad/deg
RAD_TO_DEG	Radians to degrees conversion factor	S	180/pi	deg/rad

≥. .•

Note 1:

$$ACT1\_TO\_VEH = \begin{bmatrix}
-\cos(x)\cos(y) & -\cos(x)\sin(y) & \sin(x) \\
-\sin(y) & \cos(y) & 0 \\
-\sin(x)\cos(y) & -\sin(x)\sin(y) & -\cos(x)
\end{bmatrix} \quad \text{where } x = 15.8167 \text{ dec}$$

## 4.2.2.4.2 ENGINE\_CG\_CMD

J

- A. Function: This module computes the OMS1 and OMS2 engine pitch and yaw servo trim commands necessary to point both engines through the vehicle center of gravity.
- B. Block Diagram: Figure 4.2.2.4.2-1
- C. Processing Rate: 1/maneuver
- D. Interface Requirements: Table 4.2.2.4.2-1
- E. Constants: Table 4.2.2.4.2-2
- F. Initialization Requirements: none



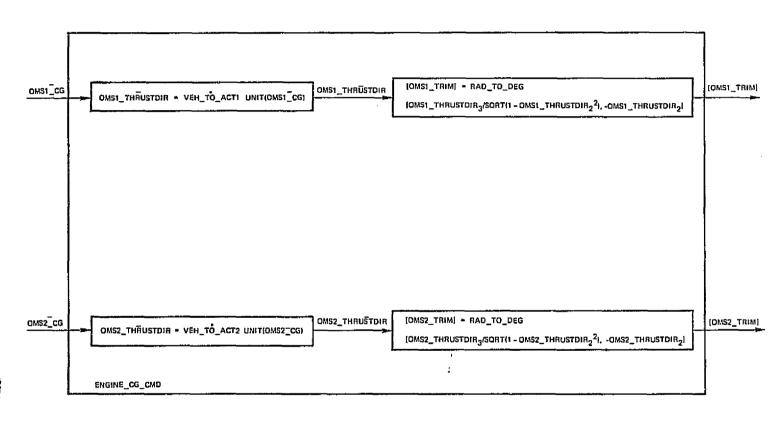


Figure 4.2.2.4.2-1. ENGINE\_CG\_CMD.

TABLE 4.2.2.4.2-1 ENGINE\_CG\_CMD INTERPACE REQUIREMENTS

HAME	DESCRIPTION	SOURCE OR DESTINATION	   TYFE 	 	 	SAMPLE   SAMPLE   FARE (HZ)
Inputs	<u> </u>			<u> </u>	1	1
ONS1_CG	Vector from OMS1 hinge point to vehicle cg, in body axes	OMS_PRETHRUST_HANEUV-	V (3) S	7 BC	f	1/maneuver
OHS2_CG	Vector from OUS2 hinge point to   Vehicle cg, in hody axes	ONS_PRETHRUST_MANEUV-   ER	V (3) S   	TBD	[ = 1 1	1/mansuver
Outputs	!		 !	i	]	
OMS1_TRIM	OBS1 engine pitch and yaw trim	TVC_LAW_PITCH-YAW	l A (2) S	TFC	deg	1/maneuver
OBS2_TRIM	OBS2 engine pitch and yaw trim	TYC_LAW_PITCH_YAW	A (2) S	TFD	i deg	 

TABLE 4.2.2.4.2-2 ENGINE\_CG\_CMD CONSTANTS

i Na BE	DESCRIPTION	I 1 TYPE	Value L	UNIT
[VEH_TO_ACT 1	Vehicle axes to CMS1 actuator axes	n (3,3)s	See Note 1	none
VEH_TO_ACT2	Vehicle axes to OHS2 actuator axes   transformation matrix	M (3,3) S	See Note 2	none
[BAD_TO_DEG	Radians to degrees conversion factor	( S L	180/pi	deg/rad

Note 1:

$$VEH\_TO\_ACT1 = \begin{bmatrix} -\cos(x)\cos(y) & -\sin(y) & -\sin(x)\cos(y) \\ -\cos(x)\sin(y) & \cos(y) & -\sin(x)\sin(y) \\ \sin(x) & 0 & -\cos(x) \end{bmatrix} \quad \text{where } x = 15.8167 \text{ deg}$$

$$VEH\_TO\_ACT2 = \begin{bmatrix} -\cos(x)\cos(y) & \sin(y) & -\sin(x)\cos(y) \\ \cos(x)\sin(y) & \cos(y) & \sin(x)\sin(y) \\ \sin(x) & 0 & -\cos(x) \end{bmatrix}$$

where 
$$x = 15.8167$$
 deg .  $y = 6.5$  deg

## 4.2.2.4.3 ENGINE\_PRETHRUST\_TRIM

أز

- A. <u>Function</u>: This module computes the OMS1 and OMS2 engine yaw and pitch servo trim commands such that the engine thrust vectors are parallel and there is no net torque on the vehicle.
- B. Block Diagram: Figure 4.2.2.4.3-1
- C. Processing Rate: 1/maneuver
- D. <u>Interface Requirements</u>: Table 4.2.2.4.3-1
- E. Constants: Table 4.2.2.4.3-2
- F. Initialization Requirements: none

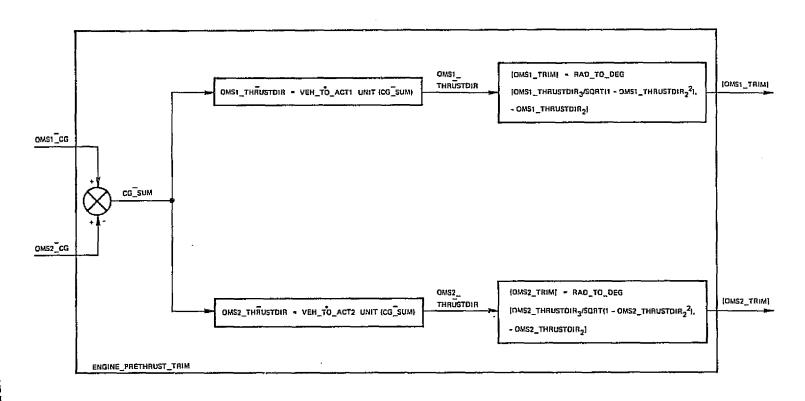


Figure 4.2.2.4.3-1. ENGINE\_PRETHRUST\_TRIM.

TABLE 4.2.2.4.3-1 ENGINE\_PRETHRUST\_TRIM INTERFACE REQUIPEMENTS

NA HE	DESCRIFTION	SOURCE OR DESTINATION	l . I TYPP	   FANGE 	l TIRU	I SAMPLE I DATE (H7)
Inputs			<u></u>	<u> </u>		<u> </u>
ONST_CG	Vector from OBS1 hinge point to   vehicle cg, in body axes	OMS_PRETHRUST_HANEUV-	V (3) S	TBD	   f 	1/maneuver
OHS2_CG	Vector from OBS2 hinge point to  Vehicle cg, in body axes	ONS_PRETRRUST_MANEUV-   EA	(Y (3) 5	TED I	<del> </del>	1/maneuver
Outputs		[			1	1
ONS1_TRIN	OMS1 engine pitch and yav trim	TVC_LAW_PITCH_YAW	A (2) S	TBC	  deq 	1/maneuver
ONS2_TRIM	OBS2 engine pitch and yaw trib   values	TYC_LAW_PITCH_YAW	I A (2) S	TED I	deg   	1/maneuver

TABLE 4.2.2.4.3-2 ENGINE\_PRETHRUST\_TRIN CONSTANTS

NAME	DESCRIPTION	TYPE	VALUE	UNIT
(VEH_TO_ACT1	Vehicle axes to OMS1 actuator axes	(H (3, 3) S	See Note 1	Inone
VEH_TO_ACT2	Vehicle axes to CMS2 actuator axes   transformation matrix	(M(3,3)S	See Note 2	Inone
PAD_TO_DEG	Radians to degrees conversi factor	ĮS	180/pi	deg/rad

Note 1:

$$VEH\_TO\_ACT1 = \begin{bmatrix} -\cos(x)\cos(y) & -\sin(y) & -\sin(x)\cos(y) \\ -\cos(x)\sin(y) & \cos(y) & -\sin(x)\sin(y) \\ \sin(x) & 0 & -\cos(x) \end{bmatrix}, \quad \text{where } x = 15.8167 \text{ deg}$$

$$VEH\_TO\_ACT2 = \begin{bmatrix} -\cos(x)\cos(y) & \sin(y) & -\sin(x)\cos(y) \\ \cos(x)\sin(y) & \cos(y) & \sin(x)\sin(y) \\ \sin(x) & 0 & -\cos(x) \end{bmatrix}$$
 where  $x = 15.8167$  deg

## 4.2.2.4.4 GUIDANCE COMPENSATION

- A. <u>Function</u>: This module provides gain and compensation filtering for the guidance loop in pitch and yaw during normal burns in the auto TVC submode.
- B. Block Diagram: Figure 4.2.2.4.4-1
- C. Processing Rate: 25 Hz
- D. Interface Requirements: Table 4.2.2.4.4-1
- E. Constants: none
- F. Initialization Requirements: Table 4.2.2.4.4-2

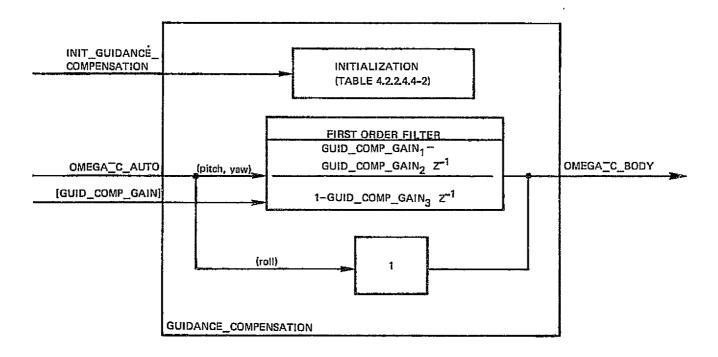


Figure 4.2.2.4.4-1. GUIDANCE\_COMPENSATION.

TABLE 4.2.2.4.4-1 GUIDANCE\_COMPENSATION INTERFACE FEQUIREMENTS

hy re	DESCRIPTION	SOUPCE OR DESTINATION	 	I I JANGE L	 	SAMELT   SAMELT   SAME (HZ)
Inputs	<u> </u>					!
OHEGA_C_AUTO	Commanded body angular rate	AUTO_TVC	V (3) S	IT BD	deg/s	25
GUID_COMP_GAIN	TVC compensation gains	CFC_RECON	A (3) S	2-engine  burn:  (6.034,  0.03332,  0.9932);  1-engine  burn:  TBD		125
INIT_GUIDANCE_COMPE- NSATION	Nodule initialization flag	OFC_RECON	1 B 1	10,1	none	125
Output	[	<u> </u>	<del></del> -	· [	<u></u>	<u> </u>
OHEGA_C_BODY	Commanded body angular rate	Roll component:  RCS ASSIST_FOLL,  TVC_LAW_ROLL  Pitch and yaw  components:  TVC_LAW_PITCH_YAW	IV (3) S	TBD	deg/s	25 

TABLE 4.2.2.4.4-2 GUIDANCE\_COMPENSATION INITIALIZATION REQUIREMENTS

INITIALIZE ON TRANSITION PROM	I INITIALIZE ON TRANSITION TO	VARIABLE	INITIAL VALUF
[INIT_GUIDANCE_COMPENSATION : [OFF	= INIT_GUIDANCE_COMPENSATION = ION I	FIRST ORDER FILTER NODE	10 I

OF POOR QUALITY

## 4.2.2.4.5 GUIDANCE\_GAIN\_RCS\_ASSIST

- A. <u>Function</u>: This module provides gain reduction for the guidance loop in pitch and yaw when the RCS DAP is helping to control the vehicle attitude in the auto TVC submode.
- B. Block Diagram: Figure 4.2.2.4.5-1
- C. Processing Rate: 25 Hz
- D. <u>Interface Requirements</u>: Table 4.2.2.4.5-1
- E. Constants: Table 4.2.2.4.5-2
- F. Initialization Requirements: none

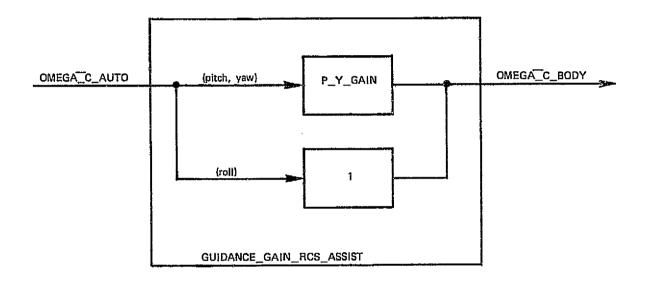


Figure 4.2.2.4.5-1. GUIDANCE\_GAIN\_RCS\_ASSIST.

TABLE 4.2.2.4.5-1 GUIDANCE GAIN RCS ASSIST INTERFACE REQUIPMENTS

t L HAME	DESCRIFICAN	SOURCE-OF   DESTINATION	I I TYPE	   FANGE 	i i i usii L	   SIMPLE   BATE (HZ)
Input	 	!	1	<u> </u>	<u></u>	
IONEGA_C_AUTO	Commanded body angular rate	AUTO_TYC	V (3) S	TBD	deg/s	125
Output		1	<u> </u>	!	1	<u> </u>
JONEGA_C_BODY	Commanded body angular rate	RCS_ASSIST_ROLL,   RCS_ASSIST_PITCH_YAW	V (3) S	ITBD	deg/s	125 1

TABLE 4.2.2.4.5-2 GUIDANCE\_GAIN\_RCS\_ASSIST CONSTANTS

I NA ME	DESCRIPTION	I TYPE	I VALUE	l unit L	l I L
P_Y_GAIN -	Pitch and yaw command gain	is I	10.16	Inone L	ĩ L

## 4.2.2.4.6 OMS\_ENG\_CMD

31

- A. <u>Function</u>: This module computes the OMS1 and OMS2 engine on commands.
- B. Block Diagram: Figure 4.2.2.4.6-1
- C. Processing Rate: 25 Hz
- D. Interface Requirements: Table 4.2.2.4.6-1
- E. Constants: none
- F. <u>Initialization Requirements</u>: Table 4.2.2.4.6-2

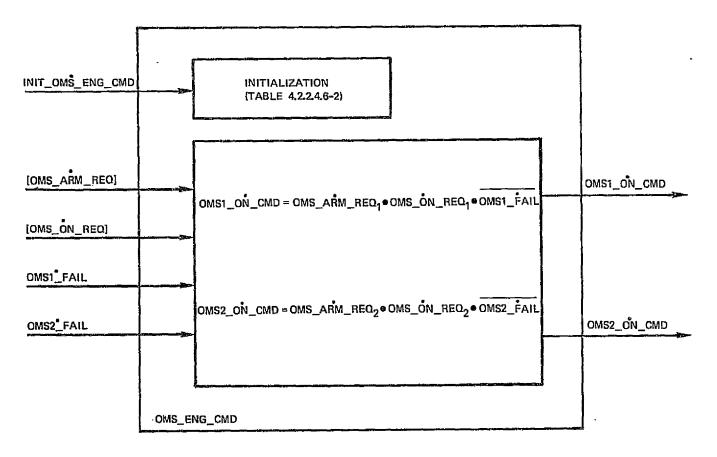


Figure 4.2.2.4.6-1. OMS\_ENG\_CMD.

TABLE 4.2.2.4.6-1 OMS\_EEG\_CHD INTERFACE REQUIREMENTS

	DESCRIPTION	SOURCE OR DESTINATION	I I I TYPE	   RAUGE 	1   UNIT 	SAMPLE   FATE (HZ)
Inputs	!	<u> </u>	!	ļ	!	[
OHS_ARH_REQ	[OMS arming request	HSC	A (2) B	10,1	none	125
OBS_ON_REQ	OMS turn-on request	INSC	A (2) B	10,1	none	125
ONS1_FAIL	OBS1 failure identified	RM	B	10,1	none	125
OHS2_FAIL	OMS2 failure identified	RU	I B	10,1	поле	125
INIT_OMS_ENG_CMD		OFC_RECON	B 	10,1	l none	125
Outputs		!	 	!	 	
oms1_on_cmd	OBS1 on command	SOP, BH, DELTA_ONEGA_ONS_ENGI-		1 [0,1 1	l none	1   25 
OBS2_ON_CHD	10HS2 on command	SOP, RH,   DELTA_OMEGA_OMS_ENGI-   NE		10,1	   Non e 	125 [

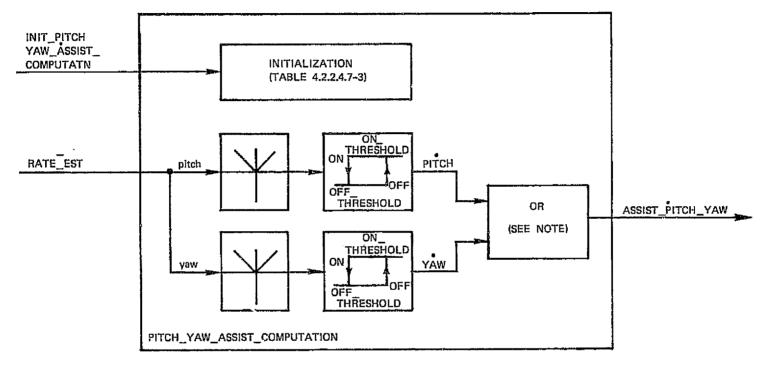
# TABLE 4.2.2.4.6-2 ONS\_ENG\_CHD INITIALIZATION REQUIREMENTS

INITIALIZE ON TRANSITION FROM	   IMITIALIZE ON THANSITION   TO	SARIABLE	INITIAL VALUF
INIT_ONS_BNG_CND = OFF	i		OFF

## 4.2.2.4.7 PITCH YAW ASSIST COMPUTATION

- A. Function: This module determines whether the TVC DAP requires assistance from the RCS DAP for yaw and pitch control, on the basis of the body rate estimate from the State Estimator. Hysteresis is incorporated to prevent noise from causing unnecessary cycling.
- B. Block Diagram: Figure 4.2.2.4.7-1
- C. Processing Rate: 25 Hz
- D. Interface Requirements: Table 4.2.2.4.7-1
- E. Constants: Table 4.2.2.4.7-2
- F. Initialization Requirements: Table 4.2.2.4.7-3

Control of the Contro



NOTE: LOGICAL OPERATION.

Figure 4.2.2.4.7-1. PITCH\_YAW\_ASSIST\_COMPUTATION.

TABLE 4.2.2.4.7-1 PITCH\_YAW\_ASSIST\_COMPUTATION INTERFACE REQUIREMENTS

I I Bahe I	DESCRIPTION	SOURCE OR DESTINATION	i I I TYPE	1     FANGE 	t TIRU 1	SAMPLE FATE (HZ)
Inputs			Ţ	ļ		<u> </u>
RATE_EST (pitch and yaw components)	BCDY ANGULAR RATE ESTIMATE	PART1_FILTER	V (3) S	TBC	deg/s   	[25]
INIT_PITCH_YAW_ASSI- ST_COMPUTATION		OFC_RECON	† B	jι,1 Ι	none I	   25   L
Output			<u> </u>	!	ļ	   
	Flag requesting RCS assistance of  TVC for pitch and yaw control  (1=reguest)	CPC_RECON	B   I 	10,1	none	125

#### TABLE 4.2.2.4.7-2 PITCH\_YAW\_ASSIST\_COMPUTATION CONSTANTS

HA HE	DESCRIPTION	TYPE	i VALUE	i UNIT i
JOH_TERESHOLD   	Body angular rate threshold for initiation or     resumption of RCS DAP assist of TVC DAP for    pitch and yaw control	is i	0 • 3 	deg/s   
OPP_THRESHOLD	[Body angular rate threshold for termination of RCS DAP assistance of TVC DAP for pitch and yaw [control		10.25	1deg/s

#### TABLE 4.2.2.4.7-3 PITCH\_YAW\_ASSIST\_COMPUTATION INITIALIZATION REQUIREMENTS

1	INITIALIZE ON TRANSITION FROM	   INITIALIZE O   T	N TRANSITION C	VARIABLE	INITIAL VALUE   INITIAL VALUE	] 
	MIT_PITCH_YAW_ASSIST_COMP8- TN = OFF	INIT_PITCH_YAW   TATH = ON	_ASSIST_CORPU-	[ 	ON I	1
1		l L		YA W 	ן סא <b>!</b>	ا 1

### 4.2.2.4.8 RCS\_ASSIST\_PITCH\_YAW

- A. Function: During the RCS assist mode of TVC operation, this module forms the pitch and yaw components of vehicle attitude and angular rate errors. Desired attitude is the integral of the commanded body rates; measured attitude is the integral of the body attitude increments derived from gimbal angle increments. Both integrals are zeroed at initialization. Attitude error is the difference between the desired and measured quantities. Rate error is the difference between the commanded and estimated body rates.
- B. Block Diagram: Figure 4.2.2.4.8-1
- C. Processing Rate: 25 Hz

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- D. <u>Interface Requirements</u>: Table 4.2.2.4.8-1
- E. Constants: Table 4.2.2.4.8-2
- F. Initialization Requirements: Table 4.2.2.4.8-3

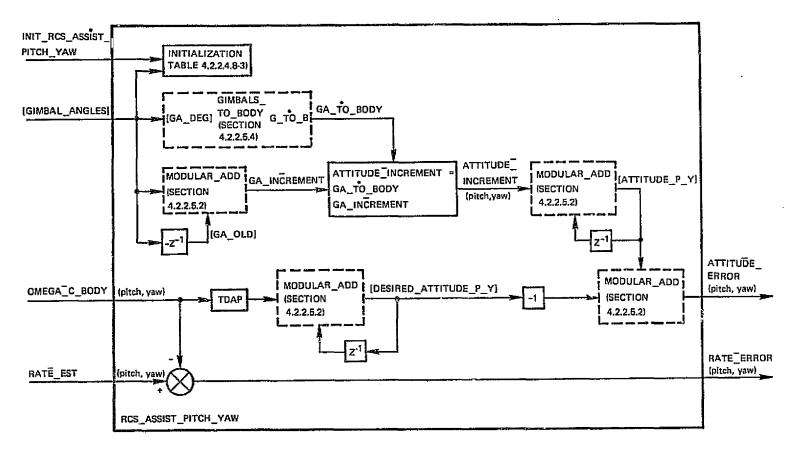


Figure 4.2.2.4.8-1. RCS\_ASSIST\_PITCH\_YAW.

TABLE 4.2.2.4.8-1 RCS\_ASSIST\_PITCH\_YAW INTERFACE REQUIREMENTS

	<del> </del>					
NA KE	DESCRIPTION	SOURCE OR DESTINATION	   	   RANGE	l I UNIT L	   SAMPLE   PATE (HZ) 
Inputs		i	i	Ţ		
OHEGA_C_BODY (pitch and yaw   components)	Commanded body angular rate	GUIDANCE_GAIN_RCS_AS-  SIST OF MANUAL_TVC	V (3) S	TBD	deg/s 	25 
DATE_EST (pitch and yav  components)	Body angular rate estimate	[PART1_FILTER	V (3) S	[ TBD	deg/s 	   25   
INIT_RCS_ASSIST_PIT- CH_YAW	Nodule initialization flag	OFC_BECON	B   B	10,1	none	   25 
GIMBAL_ANGLES	INO gimbal angles	I SOP	A (3)	-180 < x  <= 180	deg     L	25   1   L
Ontputs			<u> </u>	[	 	   
ATTITUDE_ERROR (pitch and yaw   components)	Body angle érror	PHASE_PLANE	(V (3) S	[TBD	deg     	
RATE_ERROR  {pitch and yaw  components}	Body angular rate error	DSC, PHASE_PLANE	V (3)	TBD	deg/s   	25 

TABLE 4.2.2.4.8-2 BCS\_ASSIST\_PITCH\_YAW CONSTANTS

i ay	HE I	DESCRIP	I KOIT	,	TYPE	·——·	/ALUE		UNIT	1 1 1
(TDAP	į P	eriod of TVC DAP cycle	1	s		0.04		s		- I L

TABLE 4.2.2.4.8-3 RCS\_ASSIST\_PITCH\_YAW INITIALIZATION REQUIREMENTS

I IBITIALIZE ON TRANSITION FROM	· · · · · · · · · · · · · · · · · · ·				
INIT_RCS_ASSIST_PITCH_YAW =   OFF		ATTITUDE_P_Y	O		

### 4.2.2.4.9 RCS\_ASSIST\_ROLL

- A. Function: During the RCS assist mode of TVC operation, this module forms the roll component of vehicle attitude and angular rate errors. Desired attitude is the integral of the commanded body rates; measured attitude is the integral of the attitude increments derived from gimbal angle increments; both integrations are zeroed at initialization. Attitude error is the difference between the desired and measured quantities. Rate error is the difference between the commanded and estimated body rates.
- B. Block Diagram: Figure 4.2.2.4.9-1
- C. Processing Rate: 25 Hz
- D. <u>Interface Requirements</u>: Table 4.2.2.4.9-1
- E. Constants: Table 4.2.2.4.9-2
- F. <u>Initialization</u> Requirements: Table 4.2.2.4.9-3

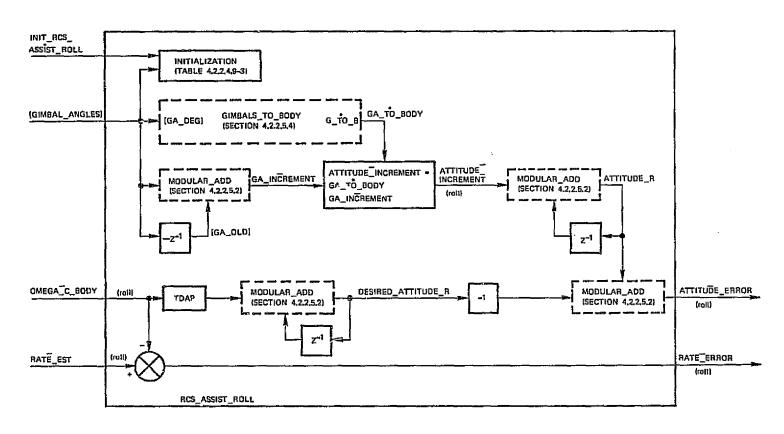


Figure 4.2.2.4.9-1. RCS\_ASSIST\_ROLL.

TABLE 4.2.2.4.9-1 RCS\_ASSIST\_ROLL INTERFACE REQUIREMENTS

HARE	DESCRIPTION	SOURCE OR DESTINATION	TYPE	   FANGF	 	
Inputs		1	<u></u>	1		Ī
OMEGA_C_BODY  {roll_component} 	Commanded hody angular rate	GUIDANCZ_GAIU_BCS_AS-  SIST,  GUIDANCE_COMPENSATION  OR MANUAL_TVC	ĺ	TER     	deg/s     	125
INIT_RCS_ASSIST_ROLL	Module initialization flag	OFC_RECON	B	[0,1	none	125
HATE_EST (roll component)	Body angular rate estimate	PART 1_FILTES	V (3) S	TEN	deq/s	125
GINBAL_ANGLES	ান্য gimbal angles	SOP	A (3) 5	-180 < x  <= 180	l   deg 	125
Outputs		<u> </u>		· !	<u></u>	<u> </u>
ATTITUDE_ERROR (roll component)	Body angle error	PHASE_P LANE	IV (3) S	TRD	l   deg 	125 
PATE_ERROR   (roll component)	Body angular rate error	DEC, PHASE PLANE	V (3) S	TBD	deg/s	125

TABLE 4.2.2.4.9-2 RCS\_ASSIST\_ROLL CONSTANTS

HA HE	DESCRIPTION	TYPE	YALUE	l untr	111
ITDAP	Period of TVC DAP cycle	is	10.04	(s	- - - - -

TABLE 4.2.2.4.9-3 RCS\_ASSIST ROLL INITIALIZATION REQUIREMENTS

I INITIALIZE ON TRANSITION FROM	INITIALIZE ON TRANSITION   TO	TARIABLE	INITIAL VALUE
INIT_RCS_ASSIST_ROLL = OFF		DESTRED_ATTITUDE_R  ATTITUDE_R    GA_OLD	0       1  0      GIMBAL_ANGLES

### 4.2.2.4.10 TVC\_LAW\_PITCH\_YAW

- Α. Function: This module closes the inner loop of the TVC DAP when RCS DAP assistance in pitch and yaw is not required. Vehicle pitch and yaw rates are derived by back-differencing the IMU angles, dividing by the time step and transforming from IMU rates to body rates. The body rates are subtracted from the commanded rates to form rate errors, which are processed by compensation filters and passed through proportional-plus-integral paths. The outputs are limited and passed on as position commands to the OMS engine actuator servos. The pitch channel compensation filter contains a sign reversal to account for a second reversal that takes place in the engine-vehicle relationship (in which positive engine pitch induces negative vehicle pitch). channel does not require such a reversal because the vehicle and actuator coordinate frames have approximately opposed Z axes, and thus positive engine yaw about the actuator Z axis induces positive vehicle yaw about the vehicle Z axis.
  - The initialization of this module includes two significant actions. The TVC DAP gains are set as an inverse function of the number of OMS engines operating; re-initialization is thus required if this number changes. Secondly, depending on the value of the initialization flag (which for this module is an integer), the integrators in the proportional-plus-integral processing may either be allowed to remain containing the final values from the previous TVC burn, or initialized to a value computed outside the module. In either case the integrator contents are immediately passed on as initial engine trim commands.
- B. Block Diagram: Figure 4.2.2.4.10-1
- C. Processing Rate: 25 Hz

3)

- D. Interface Requirements: Table 4.2.2.4.10-1
- E. Constants: Table 4.2.2.4.10-2
- F. Initialization Requirements: Table 4.2.2.4.10-3

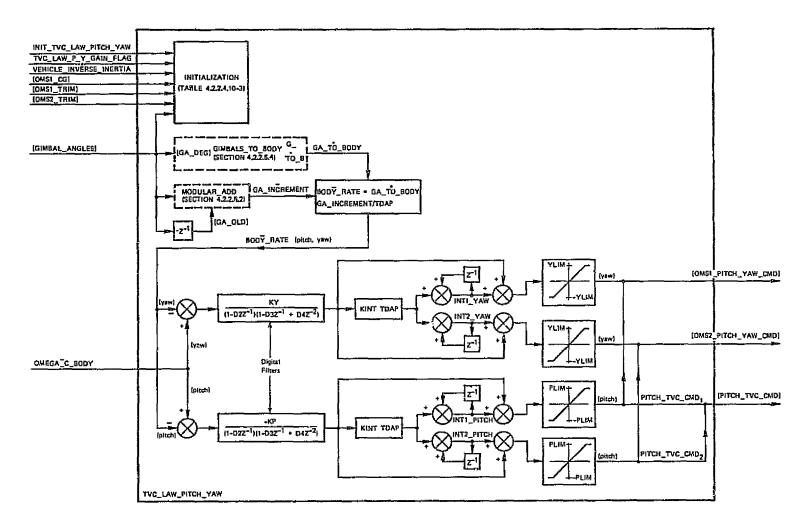


Figure 4.2.2.4.10-1. TVC\_LAW\_PITCH\_YAW.

TABLE 4.2.2.4.10-1 TVC\_LAW\_PITCH\_YAW INTERPACE REQUIREMENTS

на ме	DESCRIPTION	SOURCE OR DESTINATION	 	   FANGE   	UNIT	SAMPLE   PATE (H7) 
Inputs				i		
OBEGA_C_BODY (pitch and yaw components)		GUIDANCE_COMPPNEATION or MANUAL_TYC	V (3) S	Ter   Ter 	deq/s	25
GIMBAL_ANGLES	IHO gimbal angles	SOP		[-180 < x]  <= 180	deg	25
OHS1_CG		OHS_PRETHRUST_HANEUV-	▼ (3) s	TBD	f	1/manenver
VEHICLE_INVERSE_INE- RTIA (pitch and yaw woments)	Inverse of vehicle inertia	SF	변(3,3) 5 l	ITAD I	1/((slug)(f) = (f))	1/maneuver
	Flag indicating number of CHS engines to burn 1 = 1 engine 2 = 2 engines	OFC_8ECON	I	1,2	non e	1/man euver
7 A H	Module initialization flag  0 = no init  1 = init using trim value derived from previous OMS burn  2 = init using OMS1_TRIM and OMS2_TAIM		J.	0,1,2	notie	25
		ENGINE_CG_CHD or ENGINE_PRETHRUST_TRIN		TRD 1	dea	1/maneuver
DHS2_TRIN		ENGINE_CG_CMD OF ENGINE_PRETHRUST_TI.IM		TPT 1	deq	1/maneuver

TABLE 4.2.2.4.10-1 TVC\_LAW\_PITCH\_YAW INTERPACE REQUIREMENTS

na me	DESCRIPTION	SOURCE OR DESTINATION	TYFE	   FANGE 	 	SAMPLE   SAMPLE   SAME (HZ)
Outputs	1		!	<u> </u>	   	<u> </u>
PITCH_TVC_CHD	Pitch Component of pitch servo  command, for OMS1 and OMS2  eugines 	TVC_BIXER	[A(2)S	[pitch:  -6 <= x  <= 6  yaw: -7  <= x <=  7	deg 	125 [ 1 
DHS1_PITCH_YAW_CHD	OBS1 engine pitch and yaw servo   commands 	SOF	A (2) S           	pitch:  -6 <= x  <= 6  yaw: -7  <= x <=  7	deg         	25   1   1   1
OMS2_PITCH_YAW_CHD	OMS2 engine pitch and yaw servo commands	I SOP	A (2) 5	pitch:  -6 <= x  <= 6  yaw: -7  <= x <=  7	deg   l   l	125 

TABLE 4.2.2.4.10-2 TVC\_LAW\_PITCH\_YAW CONSTANTS

į description	į TYPE	AYLOE	TIRU
Pitch/yaw autopilot-vehicle gain product	į s	10.0109	Inone
OMS1 and OMS2 pitch command limit	<u> </u> s	16	deg
10HS1 and OHS2 yaw command limit	s	17	deg
Integrator gain	is	10.16	none
Filter coefficient	s	0.7857	none
Filter coefficient	5	1.7376	none
Filter coefficient	Į S	0.78845	none
Two-engine thrust value	is	12000	1bf
Period of TVC DAP cycle		0.04	s
	Pitch/yaw autopilot-vehicle gain product   OMS1 and OMS2 pitch command limit   OMS1 and OMS2 yaw command limit   Integrator gain   Filter coefficient   Filter coefficient   Filter coefficient	Pitch/yaw autopilot-vehicle gain product   S     OMS1 and OMS2 pitch command limit   S     OMS1 and OMS2 yaw command limit   S     Integrator gain   S     Filter coefficient   S     Filter coefficient   S     Filter coefficient   S     Iwo-engine thrust value   S	Pitch/yaw autopilot-vehicle gain product   S   C.0109     OMS1 and OMS2 pitch command limit   S   6     OMS1 and OMS2 yaw command limit   S   7     Integrator gain   S   O.16     Filter coefficient   S   0.7857     Filter coefficient   S   1.7376     Filter coefficient   S   0.78845     Two-engine thrust value   S   12060

TABLE 4.2.2.4.10-3 TVC\_LAW\_PITCH\_YAW INITIALIZATION FEQUIREMENTS

INITIALIZE ON TRANSITION FROM	I INITIALIZE ON TRANSITION TO	Y ARIABLE	I INITIAL VALUE
	INIT_TYC_LAW_PITCH_YAW = 1	I KY	Note 1
	į .	KP	Note 2
		Nodes (3 each)	ũ
 	! !	IGA_OLD	  GIMPAL_ANGLES   
INIT_TVC_LAW_PITCH_YAW = 0	IHIT_TYC_LAW_PITCH_YAW = 2	INT1_PITCH	OHS1_TFIM\$(1)
		INT1_YAW	OM51_TIIM\$ (2)
		IHT2_PITCH	OHS2_TRIM\$ (1)
1 	1 1 1	!INT2_YAW !	  OMS2_TRIM\$(2)

Note 1:

T VEHICLE\_INVERSE\_INERTIA3,3 OMS1\_CG1 TVC\_LAW\_P\_Y\_GAIN\_FLAG

Note 2:

T VEHICLE INVERSE INERTIA2,2 OMS1\_CG1 TVC\_LAW\_P\_Y\_GAIN\_FLAG

# 4.2.2.4.11 TVC\_LAW\_ROLL

- A. <u>Function</u>: This module provides control of the vehicle in roll during two-engine TVC burns.
- B. Block Diagram: Figure 4.2.2.4.11-1
- C. Processing Rate: 25 Hz
- D. Interface Requirements: Table 4.2.2.4.11-1
- E. Constants: Table 4.2.2.4.11-2
- F. <u>Initialization Requirements:</u> Table 4.2.2.4.11-3

C.3

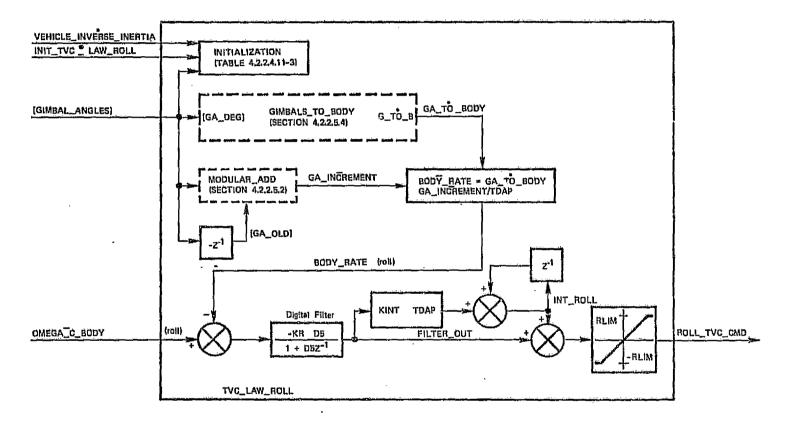


Figure 4.2.2.4.11-1. TVC\_LAW\_ROLL

TABLE 4.2.2.4.11-1 TVC\_LAW\_ROLL INTERFACE REQUIREMENTS

нане	descriftion	SOURCE OR DESTINATION	   TYPE	   RANGE	l UNIT	   SAMPLE   PATE (NZ)
Inputs			<u> </u>	<u> </u>	 	 !
OMEGA_C_BODY (roll component)	Commanded body angular rate	GUIDANCE_COHPENSATION OF MANUAL_TVC	V (3) 5	TBD	deg/s 	   25 
INIT_TYC_LAW_ROLL	Module initialization flag	OFC_RECON	B	10,1	none	25
GINBAL_ANGLES	INU gimbal angles	SOP		-180 < x  <= 180	deg 	25
VEHICLE_INVERSE_INE- RTIA (roll moment)	Inverse of vehicle inertia	SP   I	И(3,3) S	T BD	1/((sluq)(f) -   (f)) 	25     
Outputs		!	<u></u>	!		
	Roll component of pitch servo command for OMS engines		   5 	(TBP	deg   	25   25

TABLE 4.2.2.4.11-2 TVC\_LAW\_ROLL CONSTANTS

илне .	DESCRIPTION	TYPE	VALUE	UNIT
į K	Roll autopilot-vehicle gain product	5	TBD	none
	Limiting value for roll component of pitch servo command for OBS engines	S	TBD	deg
KINT	Integrator gain	S	TBD	none
[D5	Filter coefficient	Ş	TRD	none
IT	Two-engine thrust value	S	12660	1bf
IX	OBS engines Y-aris separation	5	14.7	f
IDAP	Period of TVC DAP cycle	S	10.04	s

TABLE 4.2.2.4.11-3 TYC\_LAW\_ROLL INITIALIZATION REQUIREMENTS

INITIALIZE ON TRANSITION FROM	INITIALIZE ON TRANSITION TO	VARIABLE	INITIAL VALUE
INIT_TVC_ROLL = OFF		FILTER_OUT	Note 1

Note 1:

K T LY VEHICLE\_INVERSE\_INERTIA\_1,1

### 4.2.2.4.12 TVC\_MIXER

- A. <u>Function</u>: This module derives the OMS1 and OMS2 pitch actuator servo commands as the difference and sum respectively of the pitch and roll TVC commands.
- B. Block Diagram: Figure 4.2.2.4.12-1
- C. Processing Rate: 25 Hz
- D. <u>Interface Requirements</u>: Table 4.2.2.4.12-1
- E. Constants: none
- F. Initialization Requirements: none

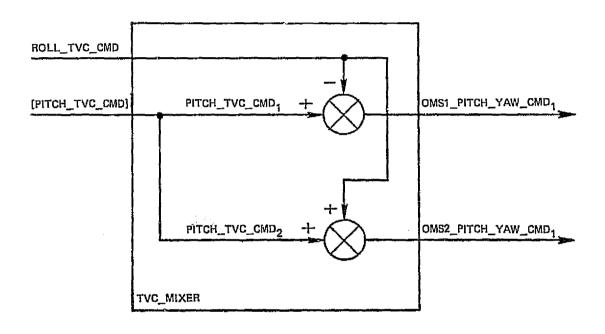


Figure 4.2.2.4.12-1. TVC\_MIXER

TABLE 4.2.2.4.12-1 TYC\_MIXER INTERFACE REQUIREMENTS

NAME	DESCRIPTION	SOURCE OR DESTINATION	TYPE	   PANGE 	l L L UNIT	   SAMPLE   FATE (HZ)
Inputs		<u> </u>	<u></u>	!		1
ROLL_TYC_CHD	Roll component of pitch servo	TYC_LAW_ROLL	is i	TBD	deg	25   25
PITCH_TYC_CHD	Pitch component of pitch servo command, for OMS1 and OMS2 engines	TYC_LAW_PITCH_YAW	] A (2) 5	TBD	deg     	125
Ouputs			<u> </u>	!		<u></u>
ONS1_PITCH_YAW_CHD (pitch element)	OMS1 engine pitch and yaw servo	SOP, RH	1 A (2) S	TED	l deg !	   25 
OMS2_PITCH_YAW_CMD [(pitch element)	10H52 engine pitch and yaw servo	SOP, RH	A (2) S	(TBD	deg	   25 

#### 4.2.2.5 Service

## 4.2.2.5.1 ANGLES\_TO\_DCM

- A. <u>Function</u>: This module generates a direction cosine matrix that transforms a vector in body coordinates to one in IMU stable member coordinates. The matrix is rectangular and thus its transpose may be used for the inverse transformation.
- B. Block Diagram: Figure 4.2.2.5.1-1
- C. Processing Rate: As called
- D. Interface Requirements: Table 4.2.2.5.1-1
- E. Constants: Table 4.2.2.5.1-2
- F. Initialization Requirements: none



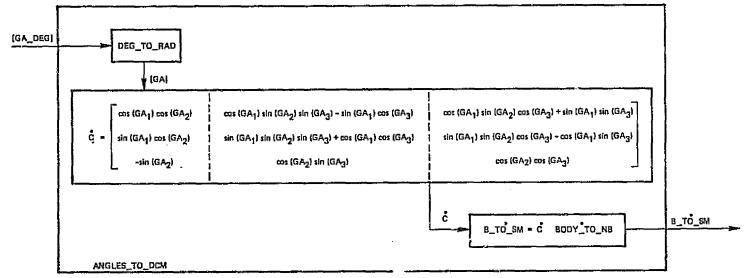


Figure 4.2.2.5.1-1. ANGLES\_TO\_DCM.

TABLE 4.2.2.5.1-1 ANGLES\_TO\_DCH INTERPACE REQUIREMENTS

NAME	DESCRIPTION	SOURCE OR DESTINATION	   TYPE 	PANGE	ONIT	SAMPLT   SAMPLT   BATT (H7)
Input	1	<u> </u>		<u> </u>		 [
GA_DEG (Note 1)	IMU gimbal angles	  Calling routine   		]-180 < x!  <= 180	deg   	1/call   1/call
Output	<u> </u>	<u> </u>	<del></del>		<u>                                     </u>	
B_TO_SH {Note 2;	Body to stable member   transformation matrix	Calling routine		-1 <= x  <= 1	none I	1/call
   	Note 1. Input parameter name.  Calling routine way use any legal  name.	 		     	       	     
	Hote 2. Assign parameter name.   Calling routine may use any legal   name.	;   	!       	] 	   	   

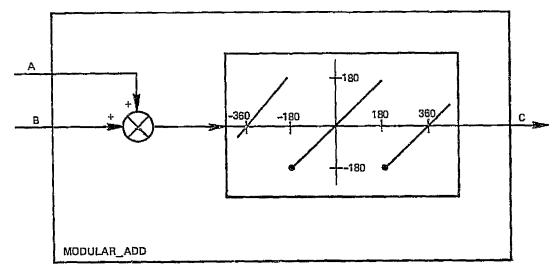
TABLE 4.2.2.5.1-2 ANGLES\_TO\_DCH CONSTANTS

NAME	DESCRIPTION	TYPE	VALUE	t I 1 UNJT I
[DEG_TO_RAD	Degrees to radians conversion factor	[5	pi/180	rad/deg
HODY_TO_NB	Vehicle to INU navigation base transformation   matrix	[M (3, 3) S   	See Note 	none       

Note 1: 
$$\cos(11^{\circ}) = 0 \quad \sin(11^{\circ})$$
  
BODY\_TO\_NB =  $\begin{bmatrix} \cos(11^{\circ}) & 0 & \sin(11^{\circ}) \\ 0 & 1 & 0 \\ -\sin(11^{\circ}) & 0 & \cos(11^{\circ}) \end{bmatrix}$ 

### 4.2.2.5.2 MODULAR\_ADD

- A. <u>Function</u>: This module adds two angles such that the sum is in the range -180 to 180 degrees.
- B. Block Diagram: Figure 4.2.2.5.2-1
- C. Processing Rate: As called
- D. <u>Interface Requirements</u>: Table 4.2.2.5.2-1
- E. Constants: none
- F. <u>Initialization Requirements</u>: none



NOTE: This is a scalar operation. For vector or array inputs, it is performed once for each element.

Figure 4.2.2.5.2-1. MODULAR\_ADD.

TABLE 4.2.2.5.2-1 HODULAR\_ADD INTERFACE REQUIREMENTS

HAME	DESCRIPTION	SOURCE OR DESTINATION	I TYPE	l RANGE	I     UNIT	SAMPLF   PATE (HZ)
Inputs		!	- <del></del> !	<u></u>		<u> </u>
A,B (Note 1)	ingles to be added	Invoking routine		TBD	deg	1/invocation
Output		1	- <del></del> 			1
C (Note 2)		Invoking routine	S   I	-180 < x  <= 180	deg	1/invocation
	Note 1. Input parameter name.  Calling routine may use any legal   name.  Note 2. Return parameter name.  Calling routine may use any legal   name.	[ ] 		 	 	 

#### 4.2.2.5.3 GA INCREMENT

- A. Function: This module increments a set of desired IMU gimbal angles, and predicts and accommodates an IMU gimbal flip. It also warns of a gimbal lock condition. The desired increments are multiplied by a sign variable (+1 or -1) and added to the desired gimbal angles, and the sum is tested to see if attainment of the new desired angles will result in lock (outer-middle gimbal angle within 1/2 degree of +90 or -90 degrees) or in flip (desired outer-middle gimbal angle greater than +90 degrees or less than -90 degrees). If lock is detected, a flag is set. If an impending flip is detected the module does the following:
  - (1) Increments the desired inner and outer gimbal angles by 180 degrees such that the result is in the range -180 to +180 degrees.
  - (2) Reflects the desired outer-middle gimbal angle about the value (+90 or -90 degrees) just passed through; e.g., 91 degrees becomes 89 degrees.
  - (3) Reverses the sign of the sign variable for future incrementations.
- B. Block Diagram: Figure 4.2.2.5.3-1
- C. Processing Rate: As called
- D. Interface Requirements: Table 4.2.2.5.3-1
- E. Constants: none
- F. Initialization Requirements: none

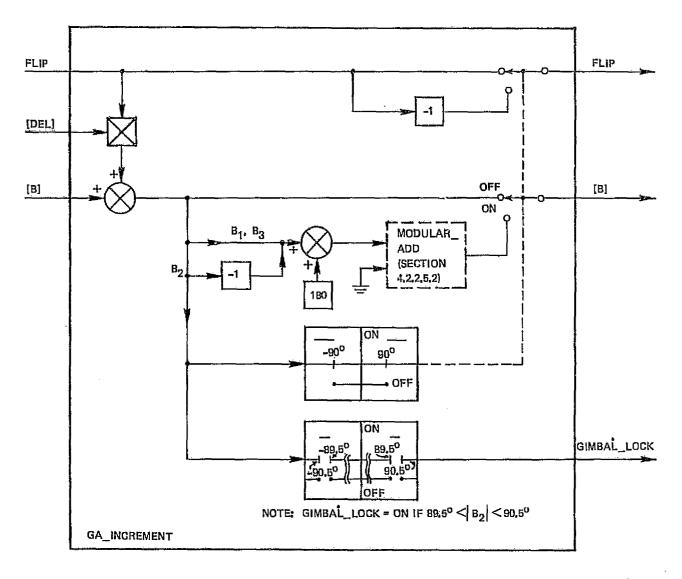


Figure 4.2.2.5.3-1. GA\_INCREMENT.

TABLE 4.2.2.5.3-1 GA\_INCREMENT INTERFACE REQUIREMENTS

нане	description	SOURCE OR DESTINATION	TYPE	I   FANGT 	! ! ONIT	SAMPLE (NZ)
Inputs			Ţ	1		1
FLIP (Note 1)	Indicator of flipped state of INU gimbal system	Calling routine	I	1-1,1	none	11/call
DEL (Note 2)	IMU gimbal angle increments	Calling routine	IA (3) 5	-180 < x  <= 180	deg	1/call
B (Note 1)	IMU gimbal angles	Calling routine	IA (3) S	-180 < x  <= 180	l deg	1/call
Outputs			1	T		
FLIP (Note 1)	Indicator of flipped state of INU	Calling routine	II !	1-1,1	none	1/call
D (Note 1)	Incremented IMO gimbal angles	Calling routine	A (3) S	-180 < x  <= 180	l deg	1/call
	  Flag indicating B\$(2) is in lock  region	Calling routine	B	10,1 1	none 	1/call
	Note 1. Assign parameter name.  Calling routine may use any legal  name.			I I		
	Note 2. Input parameter name.  Calling routine may use any legal  name.			1 1	!     	
		I	سبب بد جردیوست علم ر		L	

## 4.2.2.5.4 GIMBALS TO BODY

- A. <u>Function</u>: This module generates a matrix that transforms IMU gimbal angle races to vehicle body rates.
- B. Block Diagram: Figure 4.2.2.5.4-1
- C. Processing Rate: As called
- D. Interface Requirements: Table 4.2.2.5.4-1
- E. Constants: Table 4.2.2.5.4-2
- F. Initialization Requirements: none

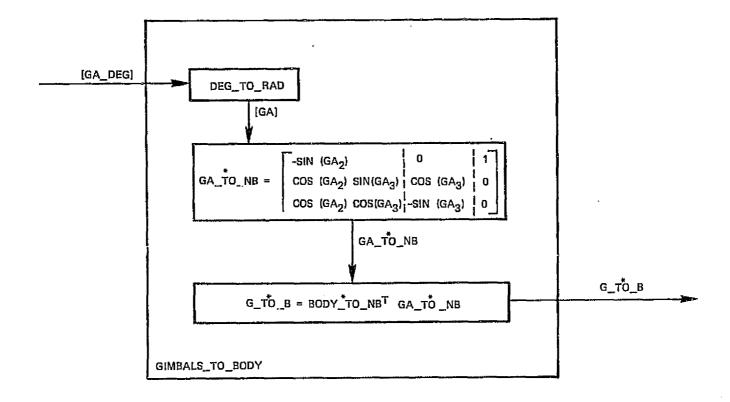


Figure 4.2.2.5.4-1. GIMBALS\_TO\_BODY.

TABLE 4.2.2.5.4-1 GINBALS\_TO\_BODY INTERFACE REQUIREMENTS

HAME	I I DESCRIPTION	SOURCE OR DESTINATION	     TYPF 	     FANGE 	!   UNIT 	SAMPLE     SAMPLE     FATT (HZ)
Input		<u> </u>	   			   1
GA_DEG (Note 1)	IBU gimbal angles	Calling routine		-180 < x  <= 180	deg   l	1/call
Output	<u> </u>	 	<u> </u>	 		
[G_TO_B (Note 2)	IMU gimbal rotation to body rotation transformation matrix	Calling routine   		-1 <= x  <= 1	none	1/call
1	Note 1. Input parameter name.  Calling routine may use any legal  name.	i	 [     	   	     	
1 1	Note 2. Assign parameter name.   Calling routine may use any legal   name.	! ! !	]       	 		

#### TABLE 4.2.2.5.4-2 GIMBALS\_TO\_BODY CONSTANTS

NAME	DESCRIPTION	TYPE	YALUE L	ONIT
IDEG_TO_EAD	[Degrees to radians conversion factor	[S	) pi/180	rad/deg
BODY_TO_NB	Vehicle TO INU navigation base transformation   watrix	H (3, 3) S	See Note   	none [

Note 1: 
$$\cos(11^{\circ}) = 0 = \sin(11^{\circ})$$
  
BODY\_TO\_NB =  $\begin{bmatrix} \cos(11^{\circ}) & 0 & \sin(11^{\circ}) \\ 0 & 1 & 0 \\ -\sin(11^{\circ}) & 0 & \cos(11^{\circ}) \end{bmatrix}$ 

## 4.2.2.5.5 BODY\_TO\_GIMBALS

- A. <u>Function</u>: This module generates a matrix that transforms vehicle body rates to IMU gimbal angle rates.
- B. Block Diagram: Figure 4.2.2.5.5-1
- C. Processing Rate: As called
- D. Interface Requirements: Table 4.2.2.5.5-1
- E. Constants: Table 4.2.2.5.5-2
- F. <u>Initialization Requirements</u>: none

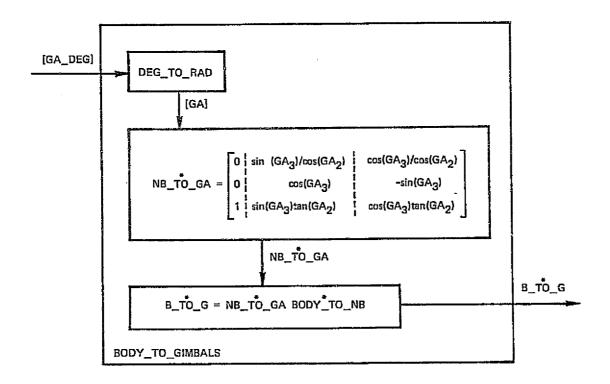


Figure 4.2.2.5.5-1. BODY\_TO\_GIMBALS.

TABLE 4.2.2.5.5-1 BODY\_TO\_GIMBALS INTERFACE REQUIPEMENTS

	INDAD TIZEZESES E BOD					
HYRE I	DESCRIPTION	SOURCE OR DESTINATION	     TYPE	     FANGE 	 	SAMPLE   FATE (HZ)
Input	 		<del></del>	   	<u> </u>	1
[GA_DEG (Note 1)	INU gimbal angles	Calling routine	A (3) 5   	-180 < x  <= 180	i deg	1/call   
Output		 	<u> </u>	<u> </u>		t
B_TO_G (Note 2)	Body rotation to IMU gimbal   rotation transformation matrix	Calling routine	H (3,3) S	-1 <= x  <= 1	i none	1/call
	Note 1. Input parameter name.  Calling routine may use any legal  name.	 	 	 	 	
		 		1 	   	1

## TABLE 4.2.2.5.5-2 BODY\_TO\_GIMBALS CONSTANTS

<u> </u>	DESCRIPTION	I TYPE	U VALUE	UNIT
IDEG_TO_RAD   eg	rees to radians conversion factor	is	p1/160	rad/deg
	ricle to INU navigation base transformation	]H(3,3)S	See Note 1	none i

Note 1:	cos(11°)	`0	sin(11°)
BODY_TO_NB =	0	1	o
	-sin(11°)	0	cos(11°)